JOINT CANNERY OUTFALL DYE STUDY REPORT
Non-tradewind Season

NPDES Permits AS0000019 & AS0000027

StarKist Samoa, Inc. and
VCS Samoa Packing Company
Pago Pago, American Samoa

July 1993

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EXECUTIVE SUMMARY

The first of two outfall dye studies has been conducted on the Joint Cannery Outfall in fulfillment of NPDES permit conditions. The field dye study was conducted, as designed, during non-tradewind conditions in February 1993. The non-tradewind dye study confirms the assumptions and predictions used to select the diffuser location and determine the mixing zone geometry. Compliance with American Samoa Water Quality Standards at the mixing zone boundary are expected under all conditions considered during the development of the mixing zone.

The dye study provides measurements of effluent dilution and wastewater plume behavior under non-tradewind oceanographic conditions. The data collected were used to document predicted diffuser performance and subsequent dilution achieved. Field observations were compared to previous model predictions. The principal findings of the study are summarized below.

Previous model predictions of initial and subsequent dilution were not done under exactly the same environmental conditions observed in the field. However, conditions were similar and the following qualitative comparisons can be made at this time as follows:

- Initial dilution was found to be as expected, with flux average dilutions across the plume apparently higher than model predictions. Diffuser nearfield performance is consistent with the model predictions used to develop the toxicity mixing zone for un-ionized ammonia.

- The plume was trapped below the surface deeper than had been expected under non-tradewind conditions. The trapping depth was approximately the same as predicted by the plume model under conditions similar to those observed. No dye was transported to or detected near or on the reef.

- Subsequent dilutions also appeared higher than model predictions had indicated.

- Dilution at the mixing zone boundary was found to be higher than model predictions indicate is necessary to meet American Samoa Water Quality Standards throughout the harbor.

Rigorous model verification is not a part of this study and will be addressed by a separate NPDES permit condition. The comprehensive model verification study will be done incorporating the results of both dye studies and results of the ongoing monitoring being conducted by the American Samoa Government.

Two fixed current meters were deployed near the diffuser and drogues were released and tracked at depths consistent with the plume trapping level. Wind observations were made from the vessel during the study. Currents were found to be essentially wind driven and not measurably affected by tidal conditions. Near bottom currents averaged about 2 cm/sec and mid-depth currents averaged about 18 cm/sec. Based on drogue trajectories, currents at the plume trapping level appeared to average 2.5 to 3 cm/sec. A net seaward current direction, at the depths occupied by the plume, was observed throughout the dye study. This current condition persisted under two distinct wind directions.

Vertical density gradient observations were made at the time of the dye study. The density gradient was relatively weak (0.4 sigma-t units between the surface and the depth of the diffuser at 176 feet) but stronger than previously used for model simulations for non-tradewind conditions. This partly accounts for the deeper than anticipated trapping level of the plume.

Field dye concentration measurements were made over a 10-hour period. Continuous readings of dye concentration were made using a calibrated fluorometer. Over 300 representative measurements were recorded during numerous vertical profiles and horizontal transects. Effluent dilutions ranging from 123:1 in the plume exiting the diffuser to over 6000:1 at the mixing zone boundary were determined.

The dispersion of the effluent plume was more intense than model predictions had indicated. It was difficult to follow the plume from the diffuser to the mixing zone boundary or to detect any dye at the mixing zone boundary. It is recommended that during the second dye study, planned for tradewind conditions in late August or early September, additional attempts be made to track and detect the plume at greater distances from the diffuser. A few other minor recommendations to enhance the second dye study are made including additional density gradient measurements, more wind data collection, and additional effluent flow determinations.

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Section 1

INTRODUCTION

This report presents the results of the February 1993 dye study performed on the Joint Cannery Outfall in outer Pago Pago Harbor, American Samoa (Figure 1-1). StarKist Samoa, Inc. (SKS) and VCS Samoa Packing Company (VCS) jointly operate and discharge treated effluent through this outfall. The outfall is operated under NPDES permits AS0000019 (SKS) and AS0000027 (VCS). The performance of two seasonal outfall dye studies is a condition of the permits. This is the first of the two required studies.

This report is organized in five sections and associated appendices. This section presents a brief background, objectives, and the general approach to the dye studies. Section 2 describes the field and data analysis methods. The results of the dye study are presented in Section 3. Conclusions and recommendations, including a discussion of compliance with the permitted mixing zone and suggestions for the second dye study, are discussed in Section 4. Section 5 provides citations for references made in the text. The Appendices contain detailed data descriptions of measurements of environmental, and dye concentration data.

BACKGROUND

In February 1992, following the implementation of high strength waste segregation and the construction of a new outfall, the canneries began discharging their treated wastewater into the outer harbor. The new outfall replaces two individual inner harbor outfalls. The Joint Cannery Outfall extends a distance of approximately 1.5 miles from the cannery locations on the north shore of the inner harbor into the outer harbor offshore of Anasosopo Point (Figure 1-1). The outfall consists of a 16-inch HDPE pipe that terminates with a multiport diffuser section located at a depth of approximately 176 feet below mean lower low water.

The diffuser section has 4 active ports on alternating sides of the pipe at a spacing of 50 feet. The diffuser ports are 5 inches in diameter and discharge horizontally. The approved zone of mixing boundary, as defined in the NPDES permits, is a circle with a radius of 1,300 feet from the center of the diffuser or the 30-foot depth contour, whichever is closer to the diffuser (Figure 1-2). The current NPDES permits are based on an approved zone of mixing. The size and location of the zone of mixing was based on environmental and engineering studies which included model predictions (CH2M HILL, 1991a; CH2M HILL, 1991b).

PURPOSE

The purpose of this study is to collect the necessary data to better understand the fate of the effluent plume. The data collected, and subsequent analysis are intended to provide direct

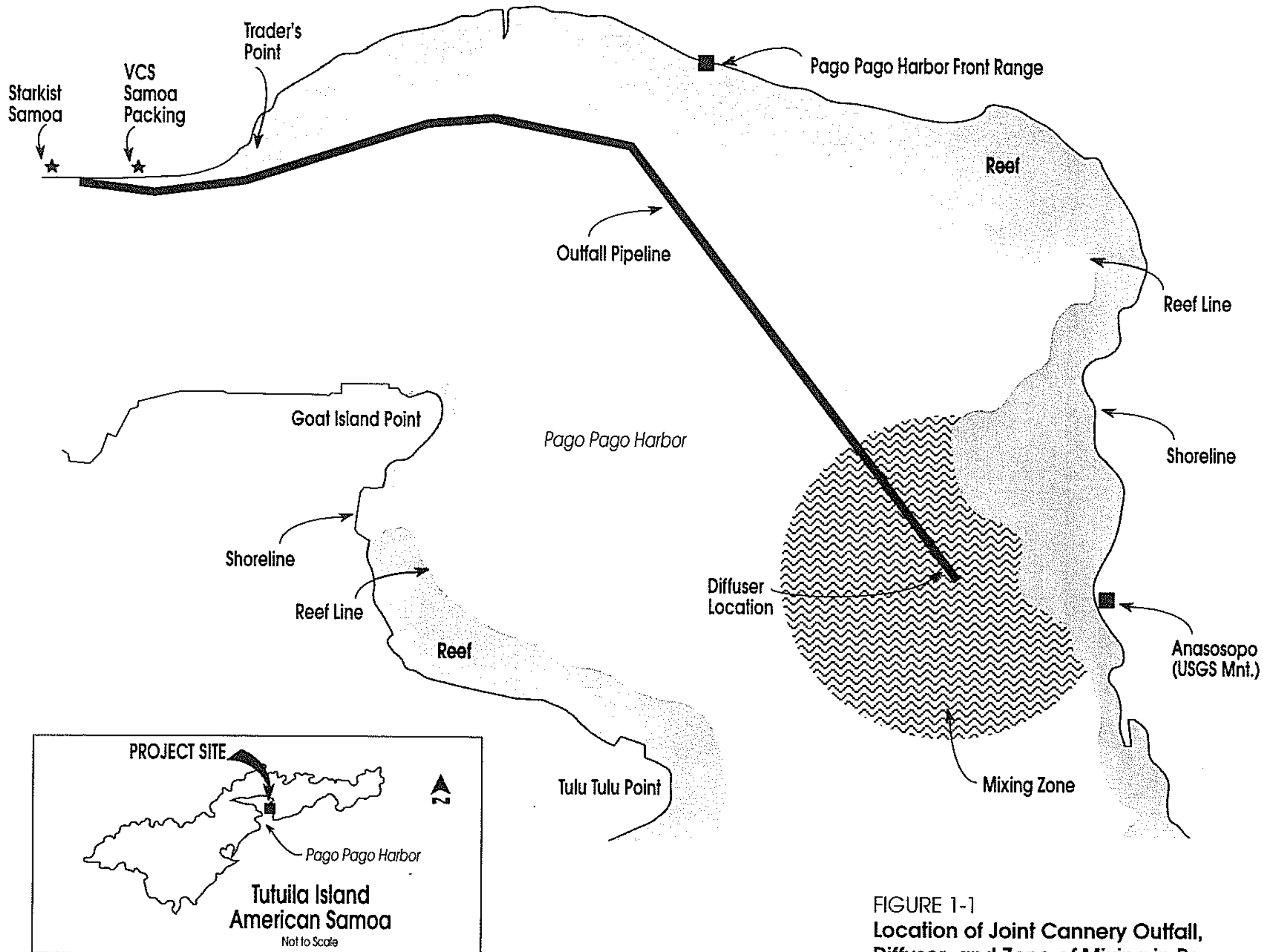


FIGURE 1-1
Location of Joint Cannery Outfall, Diffuser, and Zone of Mixing in Pago Pago Harbor

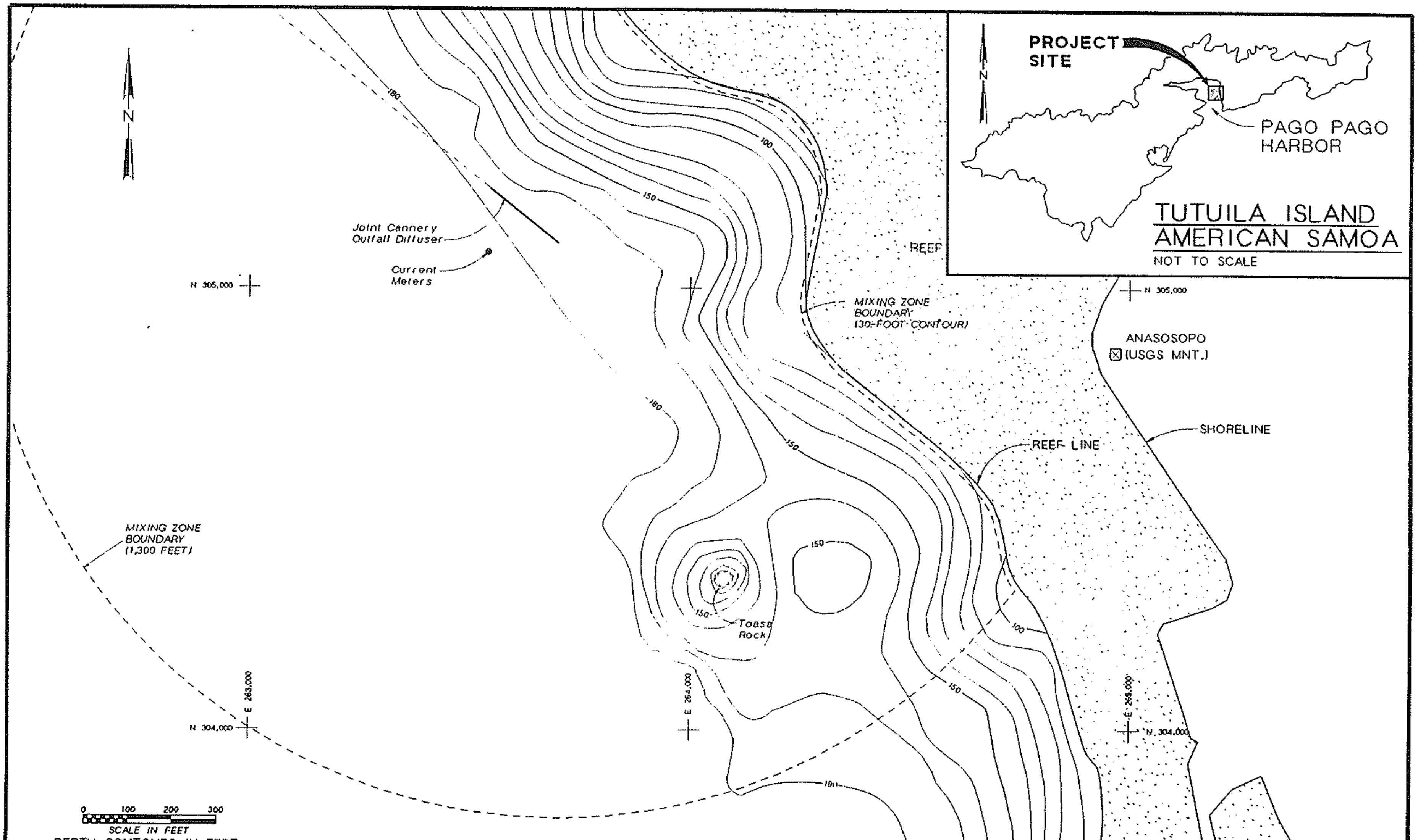


Figure 1-2
JOINT CANNERY OUTFALL DYE STUDY AREA AND MIXING ZONE BOUNDARY

evidence of plume behavior, dilution achieved, and dispersion of the wastefield. The NPDES permits issued to each cannery require two dye or tracer field studies as described in Part F of the permits (effective date of the permits is 27 October 1992). The permit condition is identical for both canneries and reads, as follows:

> *"Within one week of the effective date of this permit, the permittee shall submit a plan to the ASEPA and EPA to perform dye and/or tracer studies in order to better understand the fate of the effluent plume. The permittee shall perform these studies twice for one year (once during each of the two primary seasons of the year) and submit its findings 30 days after conducting each study. The date of the first study must be approved by USEPA and ASEPA and shall occur at the earliest possible time a distinct oceanographic season is in effect and no later than four months of the effective date of the permit.*

The final study plan, including the draft study plan and response to comments on the draft plan, for this study is provided as an addendum to this report. The first field study, the subject of this report, was conducted in February 1993 and the second is scheduled for the tradewind period of August/September 1993. Data processing and analysis was conducted, as described in Sections 2 and 3, during March through May of 1993. A status report was issued with a summary of study results on 7 June 1993. Recommendations for changes to the study plan for the second dye study are presented in Section 4 below.

SELECTION OF STUDY PERIODS

The dilution studies have been scheduled during representative "critical conditions". Critical conditions are defined as those environmental conditions that result in the lowest initial dilution for the effluent flow. The most important environmental parameters involved are current speed and direction, water depth, and density variations in the vertical direction. For the Joint Cannery Outfall in Pago Pago Harbor critical conditions are not easily targeted since the currents are generally wind driven, the outfall is deep so the plume is generally trapped below the surface, and the receiving water density gradients are small.

The dye study was conducted over a tidal cycle to account for any influence of tidal effects on the plume behavior. Variations of environmental parameters over a tidal cycle in Pago Pago Harbor are small because the tidal elevation change is small (less than 1 meter) relative to the depth of the harbor. Most of the environmental variability is found on a seasonal basis and is associated with seasonal wind patterns.

Two distinct oceanographic seasons represent the extremes in current patterns and density structure in Pago Pago Harbor. The non-tradewind season is most pronounced in January and February. This first dye study was completed during the middle of February, and the wind conditions were typical of non-tradewind conditions (north-northeast winds). The tradewind season occurs from May through October. The second dye study is planned for late-August or early September when the most intense tradewind conditions are found.

APPROACH

This study was designed to obtain accurate measurements of dye injected and completely mixed into the effluent (wastewater tracer) and released through the outfall diffuser. The dye study is intended to provide direct measurements of nearfield and farfield dilution. Dilution of the wastewater was determined by continuously injecting fluorescent dye into the discharge at a controlled rate for a period of approximately 13 hours. The horizontal and vertical distribution of the resulting plume was measured throughout a tidal cycle during daylight hours.

Environmental parameters that influence plume buoyancy and trajectory were also measured and recorded including: current speed and direction, tide height, water temperature, conductivity (salinity), and wind speed and direction. Dye measurements were taken at the edge of the designated zone of mixing, within the zone of mixing, and at distances beyond the zone of mixing.

Field data have been processed and are presented in graphical and tabular formats. Supporting data have been included in the report appendices. The data collected during the dye study will be used to verify previous modeling in a separate study (Part J in the NPDES permits). The models used were applied to critical conditions, and verification of the models with dye study data will provide the desired confidence in wastefield dilution and transport predictions for worst case conditions. Data from the two seasonal dye studies data will provide an overall evaluation of the measured dilutions in terms of compliance with American Samoa water quality standards.

Section 2

STUDY METHODS

A 42-foot vessel was used as the sampling platform for the study, and a field crew of three conducted the field measurements. On February 16th, a pre-study dye injection and field measurement test was conducted to determine the appropriate dye injection rate, measure the plume trapping level, and mark the outfall diffuser with buoys. The water column profiles for density stratification and dye measurements were used to select the depths for the current meters to be placed on the array. The dye measurement profiles indicated that the wastewater plume was trapped below 100 feet water depth. The current meter array was deployed, and marker buoys were placed to denote the mixing zone boundary north, south and west of the diffuser. The dye study was conducted the following day, February 17, 1993. This section describes the equipment and procedures used during the study.

FIELD EQUIPMENT AND CALIBRATION

The implementation of the field dye study, and the resulting quality of the data collected, required careful attention to equipment suitability and calibration. The equipment used, and the calibration procedures followed, are described below. The quality assurance and quality control procedures are described at the end of this section. Additional information is available from the manufacturers operations manuals listed in the references section of this report.

Equipment Inventory

The dilution study field equipment included dye injection pumps, survey navigation instruments, field sampling pumps, fluorometers, sampling vessel, radios, and other equipment including backup units. The field equipment used for the dilution study, their use and performance standards are listed in Table 2-1.

The 42-foot vessel F/V Tasi II was used as the work platform for all measurements.
Field sample positioning was performed using a Motorola Mini-Ranger III navigation system with established transponders on land and the receiver/transmitter unit on the survey vessel. The project staff on the vessel were equipped with hand-held radios to allow communication with the dye injection station.

Equipment Calibration

All equipment was assembled at CH2M HILL's Bellevue office prior to the beginning of the dye study to allow for inspection, operation testing, and calibration. Each instrument was checked and, if appropriate, calibrated upon its arrival in Pago Pago to confirm that it was in working condition. The fluorometers were calibrated immediately prior to the beginning of the dye study and immediately following the field measurements. Calibration methods for each instrument are described below.

Table 2-1
Field Equipment for Joint Cannery Dilution Study

Equipment Item	Purpose	Number of Units	Accuracy Standard
Turner Model 10 and Model 10-AU Fluorometers	Fluorescent dye measurement by flow-through and cuvette systems	2	Detection to 0.1 ppb
Seabird SBE 19 CTD	Measure conductivity, temperature, and depth	1	Conductivity $\pm$0.001 S/m Temperature $\pm$0.001 °C Depth = 0.5% of full scale
Compaq SLT Computer	Set up and record Seabird CTD data	2	
Motorola Mini-Ranger III System	Microwave positioning System with 3 shore based transponders	1	$\pm$2 meters (range)
FMI Positive-displacement Pump	Used for dye injection into effluent at constant rate	1	0.2 ml/min
Masterflex Peristaltic Pump	Backup pump for dye injection into effluent at constant rate	1	0.2 ml/min
1/3-hp Submersible Pump	Pumps receiving water from depth through fluorometer	2	
InterOcean S4 Current Meter	Measure current speed and direction during the dye test	2	+/- 0.2 cm/sec; 0.5 degrees
Motorola Hand-held VHF Radios	Communication ship-to-shore	4	

Dye Pump. An FMI positive-displacement piston pump was used to inject dye directly into StarKist's pressurized outfall pipe immediately downstream of StarKist's effluent pumps (downstream of the surge tank). This pump is designed to deliver a constant discharge rate under pressures as high as 100 psi. The pressure at the injection site measured 40 psi. The dye pump was tested and calibrated at the dye injection site prior to the test injection and dilution study. The pump flow rate was calibrated with the dye at ambient temperature on February 16, 1993, by repeatedly discharging dye into a graduated cylinder for a fixed period of time at various flow rate scale settings.

During the pre-study test injection on February 16th, dye was also injected into the outfall line under pressure and initial dye samples were collected 200 feet downstream of Samoa Packing's effluent line to confirm that the target initial dye concentration was being met. According to the manufacturer (Fluid Metering, Inc., 1988) reproducible metering accuracy of less than 1-percent can be expected when handling medium-viscosity fluids if fluid differential pressure, fluid viscosity, and electric line voltage remain constant. To verify that none of these factors affected dye flow rates during dye injection, dye flow rates were verified and logged prior to the start and at the end of dye injection and the cumulative dye volume pumped was recorded.

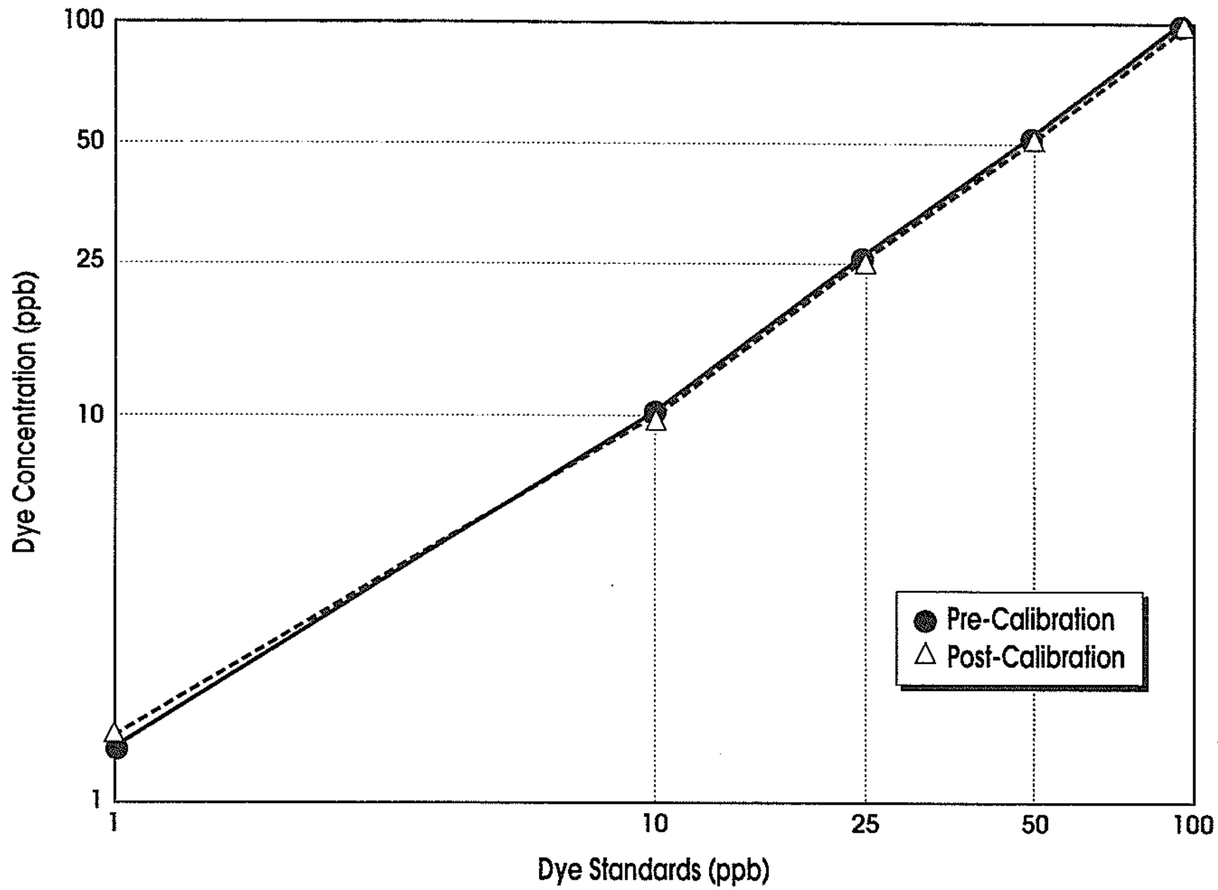
Fluorometers. Two fluorometer units were setup and calibrated to accurately read dye concentrations (as parts per billion) in the range of 0.1 to 100 ppb according to the manufacturer's specifications (Turner Designs,1992; Wilson et al., 1991). All dye measurements were made using the calibrated Turner Design Model 10-AU fluorometer. The second fluorometer was available as a backup. Both fluorometers were calibrated on February 16th, prior to the pre-study dye injection test, to confirm that both were performing at the required level of accuracy.

The fluorometer was calibrated on the day prior to the dye study by using known dye concentrations ranging from zero to 100 parts per billion (ppb). The fluorometer was calibrated to give a reading of 10.0 on the least sensitive scale (min. sens. scale) with a dye concentration of 100 ppb, and a reading of 0.0 on the most sensitive scale (31.6x scale) when the dye concentration was zero. Calibration checks using intermediate concentrations confirmed that the fluorometer response was acceptably linear over this range. The calibration was verified immediately upon completion of the study.

The temperature of the pre- and post-study fluorometer calibration standards was 76°F and 77°F, respectively. All dye standards were made with background receiving water from Pago Pago harbor for dilution, to compensate for any interference or background fluorescence. Figure 2-1 shows the pre- and post-study plots of the fluorometer calibration data. There were no significant differences between the pre- and post-study calibrations. Therefore, dye measurements did not have to be corrected for calibration drift.

CTD, and Current Speed and Direction Instruments. The SeaBird-19 conductivity-temperature-depth (CTD) instrument was calibrated by the manufacturer (Sea-Bird Electronics, 1989) before conducting the dye study. Calibration data were applied during data reduction and no subsequent adjustments were applied to the data. The InterOcean S4 current meters are maintained within calibration limits by factory procedures (InterOcean Systems, 1991) and are periodically checked for accuracy.

Mini-Ranger Navigation System. The Mini-Ranger was calibrated to the manufacturer's specifications (Motorola Inc., 1987) prior to conducting the dye study. The transceiver unit and transponders were checked against known distances using a calibration range maintained by the National Ocean Service at Sand Point, Seattle, Washington.



PRECALIBRATION	POSTCALIBRATION
Feb. 16, 1993	Feb. 18, 1993
Time: 1800	Time: 0830
Temp: 76°F	Temp: 77°F
Analyst: R.T. Coyner	Analyst: R.T. Coyner

FIGURE 2-1
Pre- and Post-Study Fluorometer Calibration Plots for Dilution Study of Joint Cannery Outfall, February 1993

DYE INJECTION PROCEDURES

Dye was injected into the outfall and initial concentration determined in a fashion designed to provide reproducible and accurate field measurements of wastefield dilution and dispersion. The dye was injected at a location selected to provide complete mixing prior to initial concentration sampling. Initial concentration samples were collected from the effluent stream throughout the field dye study. The procedures, dye injection and sampling points, and measured initial concentrations are described below.

Effluent Flow

Effluent from StarKist's treatment system is metered as it flows into the surge tank. Three pumps discharge from the surge tank into the outfall pipe. The number of pumps discharging depends on the level of effluent in the surge tank. The discharge rate from the surge tank is not uniform. Effluent from the VCS Samoa Packing treatment system is metered as it flows into an 8-inch line that joins the 16-inch outfall under the facility's dock. There is no flow meter in the outfall downstream of the point where the effluent from the two plants combine but flows can be determined from initial dye concentrations as described below. Average combined effluent flow from the canneries during the dye study was determined to be about 2.5 mgd.

The dilution study was conducted under normal plant production flows. The distance from the VCS Samoa Packing discharge connection to the outfall line to the outfall diffuser terminus is approximately 8,300 feet. The travel time from the canneries to the outfall was measured during the pre-study dye injection to be approximately 1 hour and 10 minutes.

Dye Injection Setup

Rhodamine WT dye was injected directly into the 12-inch outfall pipe immediately downstream of the effluent pumps that discharge from StarKist's surge tank. From the dye injection point, the outfall line makes three bends and then enlarges from a 12-inch to a 16-inch line at 100 feet past this injection site. The injection location is 240 feet upstream of where the 8-inch VCS Samoa Packing outfall line intersects the 16-inch outfall pipe.

The dye injection was accomplished using a positive-displacement (piston type), variable-rate pump connected to a 1/4-inch pressure tubing. A pressure valve was removed from the outfall line and replaced with a fitting with a reducer from 1-inch to 1/4-inch for the injection pump tubing connection. Two pumps were setup and their flow was calibrated with the pump head and tubing attached. One pump, a Masterflex peristaltic pump, served as the standby backup during the dye injection.

Based on the observed concentrations in the harbor during the pre-study test injection, the FMI positive-displacement pump was set to inject at a flow of 30 milliliters per minute into the effluent. This flow rate was maintained throughout the injection period. Dye injection began at 0625 and ended at 1630 on February 17, 1993.

Initial Dye Samples

The initial dye concentration in the effluent was determined by collecting effluent samples from a sampling port installed 450 feet downstream from the injection site and 210 feet downstream of the VCS Samoa Packing connection to the outfall line. The initial dye sampling line was connected to an air vent structure on the top of the 16-inch outfall line, located underwater. A diver attached a valve and sampling hose to the air vent and ran the sampling tube to the surface, where a second shutoff valve was attached. Turbulent mixing in the outfall between the injection and sampling ports was considered sufficient for complete mixing of the dye with the wastewater.

The effluent flow and initial dye concentration in the effluent were determined approximately every 45 minutes throughout the dye injection period. The dye pumping rate was confirmed before and after the study. Total consumption of dye during the study was determined as a check on the assumed injection rates. The effluent flow rate from both the VCS Samoa Packing and StarKist treatment plant were recorded between initial dye sample collections. These initial dye samples were stored in a cool dark chest. On the day following the study, the initial samples were diluted 50:1 with background receiving water, and the fluorescence was measured. Figure 2-2 presents the measured initial dye concentrations for the combined effluent.

The effluent flow rate from StarKist's surge tank varied as the tank filled and then was pumped out, and this variation in pumping discharge rate from StarKist's surge tank is shown in the initial dye concentrations. The initial dye concentrations increased as the discharge rate from StarKist's surge tank decreased, and then the initial dye values decreased as StarKist's discharge rate increased. Table 2-2 lists the effluent flow rates and initial dye concentrations as determined in the field. The variability in initial concentrations was accounted for in the data processing and analysis as described in Section 3 below.

FIELD MEASUREMENTS

The procedures used for field measurements of dye concentrations and associated environmental parameters are described below. Field measurements of dye concentrations must be processed to correct for a number of factors. The procedures used and the basis of the corrections applied during data processing are also described below.

Current, Wind, and CTD Measurements

Two InterOcean S4 current meters were deployed on a cable array at depths of 170 feet and 100 feet. The array was deployed approximately 125 feet southwest of the center of the outfall diffuser to provide *in situ* current measurements during the period of the dilution study. The InterOcean S4 is an electromagnetic current meter with a solid state 64K random access memory and is programmed to record and average current speed and

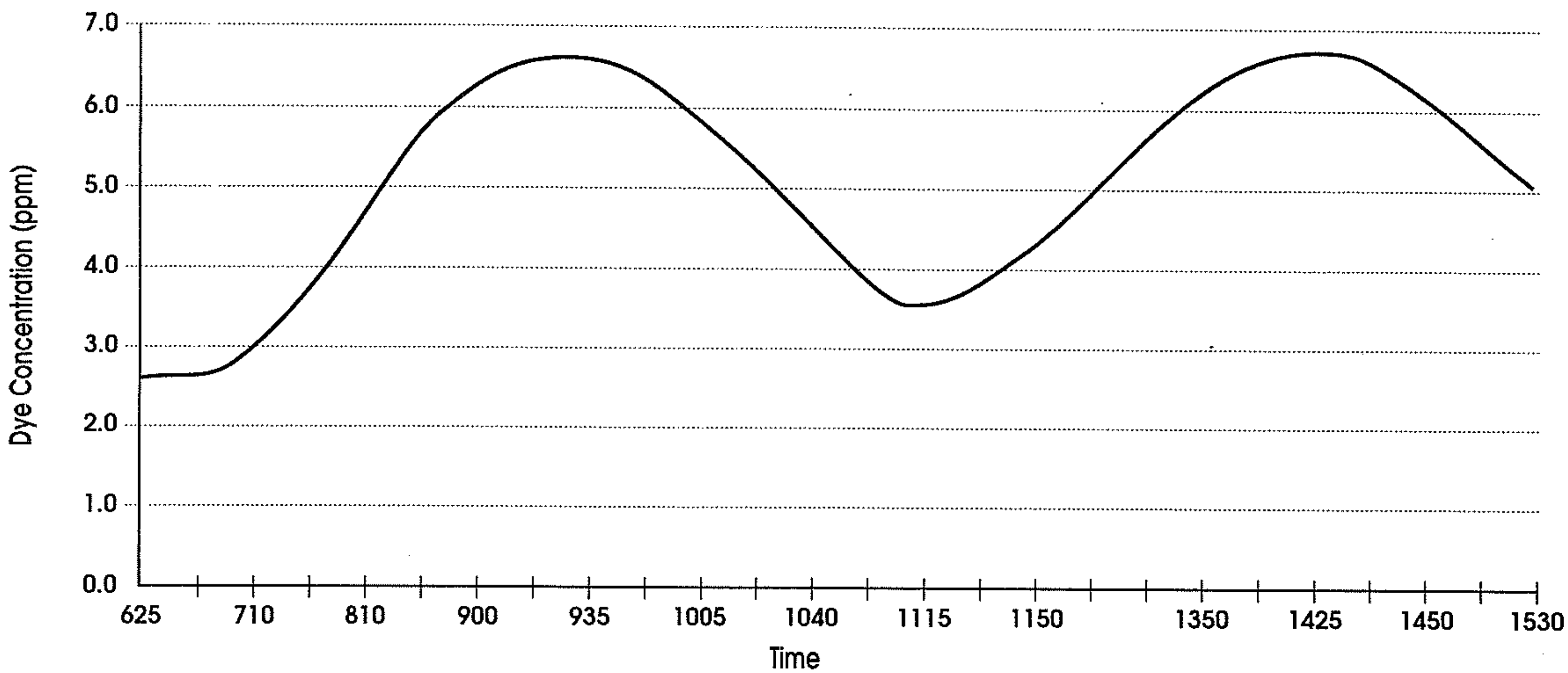


FIGURE 2-2
Initial Dye Concentrations During Dilution Study on February 17, 1993

directions at various intervals. The meter was programmed to turn on every 10 minutes for 3-minutes, collect readings every 1/2 second, and then record 3-minute average values. The current speed and direct measurements are presented in the result section of this report.

Table 2-2
Initial Dye Concentrations and Effluent Flow Rates
February 17, 1993 Dye Study

Time (Local)	Initial Dye Concentration[1] (ppm)	StarKist Flow to Surge Tank[2] (gpm)	StarKist Flow from Surge Tank[3] (gpm)	Samoa Packing Flow[2] (gpm)	Total Flow Through Outfall[3] (gpm)
0625	2.6	850	2400	640	3,040
0710	3.0	850	1990	640	2,630
0810	5.0	850	940	640	1,580
0900	6.0	850	690	630	1,320
0935	6.5	800	600	620	1,220
1005	5.7	800	770	620	1,390
1040	4.5	800	1130	630	1,760
1115	3.5	850	1630	630	2,260
1150	4.3	850	1210	630	1,840
1350	5.5	875	820	600	1,430
1425	6.5	850	620	600	1,220
1450	6.0	950	720	600	1,320
1530	5.0	925	980	600	1,580
Average	4.9	854	1115	622	1738

[1] Measured from samples collected.
[2] Determined from measured flow records.
[3] Calculated from initial concentrations and known flows.

Due to the possible effects of winds on water transport, wind observations were recorded on the vessel throughout the dilution study field testing. The S4 meters also recorded temperature, conductivity, and depth (at the bottom meter only). The SeaBird CTD was used concurrently with the fluorometric sampling and continuously recorded conductivity temperature and depth at the location water was being sampled. The SeaBird was also used to determine ambient stratification of the receiving water. The wind, ancillary current meter data, and CTD data are provided in Section 3 and the appendices, as appropriate.

Dye Measurements

A Turner Design Model 10-AU fluorometer, fitted with a flow-through door and equipped with a hose, submersible pump, and Seabird conductivity, temperature, and depth profiling instrument (CTD), was used to measure dye concentrations. When the vessel was positioned at the appropriate distance from the diffuser, the pump and CTD were lowered into the water. Sampling depths, temperature, salinity, and dye concentration were recorded throughout the conduct of each profile and transect.

The plume was tracked using drogues. An initial profile at the diffuser location was done to locate the plume centerline (lowest dilution). Once the center of the plume was found a windowshade drogue was set at that depth. The surface float attached to the drogue was then followed and profiles were taken along the drogue trajectory. The drogue trajectories also provide indications of current patterns in the vicinity of the diffuser.

Because of the weak currents, and concomitant slow drogue movement, the drogues are only approximate indicators of plume location and become less reliable as the distance from the diffuser increases. However, for areas within the mixing zone the drogues appear to be sufficient as markers of plume location, although not necessarily remaining on the plume centerline. The sampling procedures were designed to search for minimum dilutions using the drogues as initial approximate indicators. Numerous profiles and transects were made in the expected vicinity (immediately downcurrent) of the wastefield to ensure that the maximum dye concentration present (and, therefore, lowest dilution) was measured. Profiles were conducted to describe the vertical extent of the wastefield and horizontal transects were conducted to document the spatial distribution of the wastefield.

A Motorola Mini-Ranger III navigation system was used to accurately determine the position of the vessel during the course of the study. Mini-Ranger shore transponders were stationed as follows: Code 1 was located on top of the navigation range marker station east of Leloaloa, and Code 4 was placed on the tramway park building. Table 2-3 provides the transponder coordinates. Operation of the transponders and the receiver/transmitter unit was confirmed on the day prior to the dye study. Both shore transponders were located at USGS benchmarks, and these sites have been used previously by CH2M HILL (1991a) for oceanographic surveys in Pago Pago Harbor.

Dye Concentration Corrections

Dye concentrations were measured and recorded in the field. Dye concentration readings may require corrections for temperatures, background dye concentration readings, linearity and drift.

Table 2-3 Location of MiniRanger Transponder Locations			
Transponder	Location	State Plane Coordinates (feet)	
		Easting	Northing
Code 1	Pago Pago Harbor Front Range Tower	261,551.58	309,857.04
Code 2	Fagatogo Tram Park Building	258,117.06	305,879.24

- Because dye fluorescence is sensitive to temperature, measurements made in the field must be adjusted to the calibration temperature. The field measurements included temperature recordings taken simultaneous with the dye readings, and the dye concentrations are then corrected for field versus calibration temperature differences. The dye measurements were corrected to the equivalent value at the calibration temperature with the following formula (Turner Designs, 1977):

$$Fc = Fs \exp [K_T(Ts-Tc)]$$

where:

K_T	=	0.026/degree
Fc	=	the corrected dye concentration
Fs	=	measured sample dye concentration
Ts	=	temperature of field measurement (measured by CTD)
Tc	=	temperature of the standards used to perform calibration (19°C)

- Background dye concentrations measured upstream of the outfall diffuser were 0.1 and 0.2 ppb on February 16th, and no correction was considered necessary for background fluorescence.

- The fluorometer was calibrated on the day prior to and the day after the dye study by using known dye concentrations ranging from 1 to 100 ppb. Background readings were also done as described above. Calibration checks using intermediate concentrations confirmed that the fluorometer response was acceptably linear over this range. (Figure 2-1)

- The pre- and post-calibrations of the fluorometer also indicated that instrument drift was nearly unmeasurable (Figure 2-1). No drift correction was considered necessary.

All dye standards were made with effluent to achieve 50 and 10 parts per million (ppm) standards, and then higher dilutions were made with background water. Table A-1 in Appendix A includes the receiving water temperature values, the uncorrected dye concentration readings, and the corrected dye concentration values.

QUALITY ASSURANCE/QUALITY CONTROL

The quality assurance/quality control objectives for the dilution study were to collect measurements of wastefield dilution and dispersion of verifiable and acceptable quality. These objectives were to be achieved by using Rhodamine WT fluorescent dye, which acts as a surrogate of the actual wastefield components and completely mixes into the effluent, allowing accurate tracking by fluorometric equipment. The quality assurance requirements for achieving the objectives were to provide:

- Verifiable dye injection rates and initial dye concentrations
- Verifiable fluorometric equipment calibration before and immediately following the dye study
- Accurate vessel positioning for wastefield measurements
- Equipment redundancy (backup fluorometer and navigation system)

To evaluate the data quality and validate the collected wastefield dye measurements, the following specific activities were completed and documented:

- Fluorometers were calibrated with known concentrations of dye before the study, the fluorometer calibration and calibration curves were checked during the dye study, and post-survey calibrations of the fluorometers were completed and indicated no significant drift in the instrument readings.
- The dye injection and initial dye concentrations were verified. During the dye injection, hourly records of effluent flow and dye injection rate were maintained. Initial concentrations of dye mixed into the effluent (prior to discharge) were collected approximately every 45 minutes and measured for dye concentrations.
- The voltage outputs on the navigation system transponders and receiver/ transmitter unit were checked before and after the field dye studies. Prestudy range calibration was done at an NOS maintained calibration range.
- The vessel location was determined by using established boundary markers and the Mini-Ranger navigation system.
- Drogues were used to determine the travel direction of the wastefield plume. Wastefield transport and current measurements observed using drogues

during the field study were verified with the current speed and direction data collected using factory calibrated current meters.

- CTD and current speed and direction instruments are maintained by factory calibration and servicing.

Section 3

RESULTS

This section presents the results of the Joint Cannery Outfall dye study including: simultaneous field measurements of wastefield dye concentrations, temperature, salinity, winds, and currents; wastefield dilution calculations from field dye measurements; and wastefield plume transport measurements from drogue tracking. Results from the measurements of the important environmental parameters are presented first, followed by the measurements of dye concentration and calculated dilutions.

The results of the study can be used to calculate whole effluent concentrations, or effluent constituent concentrations, following dilution as discussed in Section 4. The effluent flow and initial dye concentration data were reviewed above in Section 2. Supporting data and documentation are presented in the appendices to this report: Appendix A, provides dye study field data collect from the vessel and Appendix B, presents the data from the S4 current meter installations.

ENVIRONMENTAL PARAMETERS

Ambient current speeds and direction, vertical density gradients, and discharge depth are important environmental variables influencing the dilution performance of the Joint Cannery Outfall. Considering the depth of discharge (176 feet, 54 meters) relatively low tidal elevation range (about 3 feet, 1 meter) for Pago Pago Harbor, the ambient current speeds and density structure are considered to be the primary receiving water conditions affecting the plume. Wind speed and direction are the principal factor controlling the currents and circulation in the Harbor. Measurements of each of the environmental parameters of interest are discussed below.

Water Levels. The field dilution study was conducted February 17, 1993 during a period that was centered on low water. The tidal water levels for the 24-hour current meter deployment period are shown in Figure 3-1, and the dilution study period is indicated on the figure. The observed water levels were recorded by the pressure sensor on the near-bottom InterOcean S4 current meter. The variations in water level are dominated by semidiurnal tidal elevation fluctuations. The observed tidal ranges, between high and low water, were less than 1 meter during the study period.

Vertical Density Profiles. Vertical profiles of temperature and conductivity variations with depth were collected at the diffuser site. Salinity and density are calculated from these measurements. The ambient conditions characterized from CTD casts taken on the day following the dye study are summarized in Table 3-1. The CTD data are provided in Appendix B. There was a relatively weak density gradient of about 0.4 sigma-t units

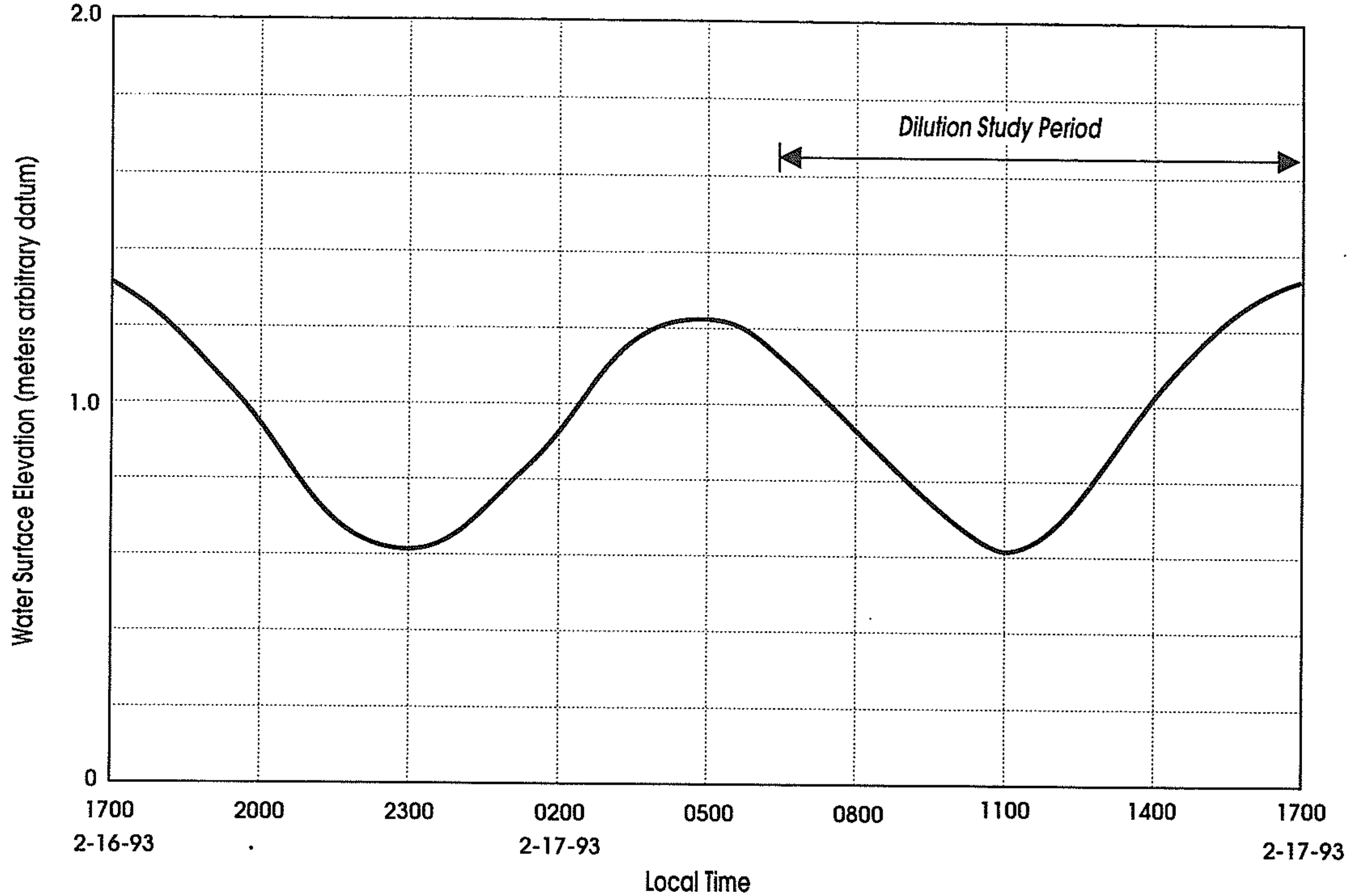


FIGURE 3-1
Observed Water Level Elevations in Pago Pago Harbor February 16th and 17th, 1993

(0.0004 gm/cm^3) through the water column in the vicinity of the diffuser. The CTD instrument was also continuously used to acquire data at the depth of sampling throughout the field measurements. These data are provided in Table A-1 in Appendix A.

Table 3-1
Ambient Density Gradient at Near the Diffuser
on February 18, 1993

Depth (meters)	Temperature (°C)	Salinity (o/oo)	Density (Sigma-t)
2.0	29.00	35.27	22.27
4.9	28.97	35.3	22.30
9.7	28.95	35.33	22.33
15.2	28.93	35.34	22.35
20.3	28.94	35.36	22.36
25.2	28.96	35.40	22.38
30.4	28.95	35.43	22.40
35.3	28.94	35.43	22.41
40.1	28.89	35.47	22.45
44.7	28.83	35.53	22.52
49.5	28.79	35.53	22.53
55.0	28.58	35.58	22.64
56.9	28.46	35.6	22.70

Wind Speed and Direction. Current and wind measurements were collected during the field dilution study to characterize the plume dynamics and wastefield transport from the Joint Cannery Outfall diffuser. Winds directly influence the water movement and the circulation throughout Pago Pago Harbor. During the field study the winds ranged from the northeast to northwest direction. These directions are representative of the non-tradewind season for which this dilution study was targeted. Wind observations made from the vessel are summarized in Table 3-2.

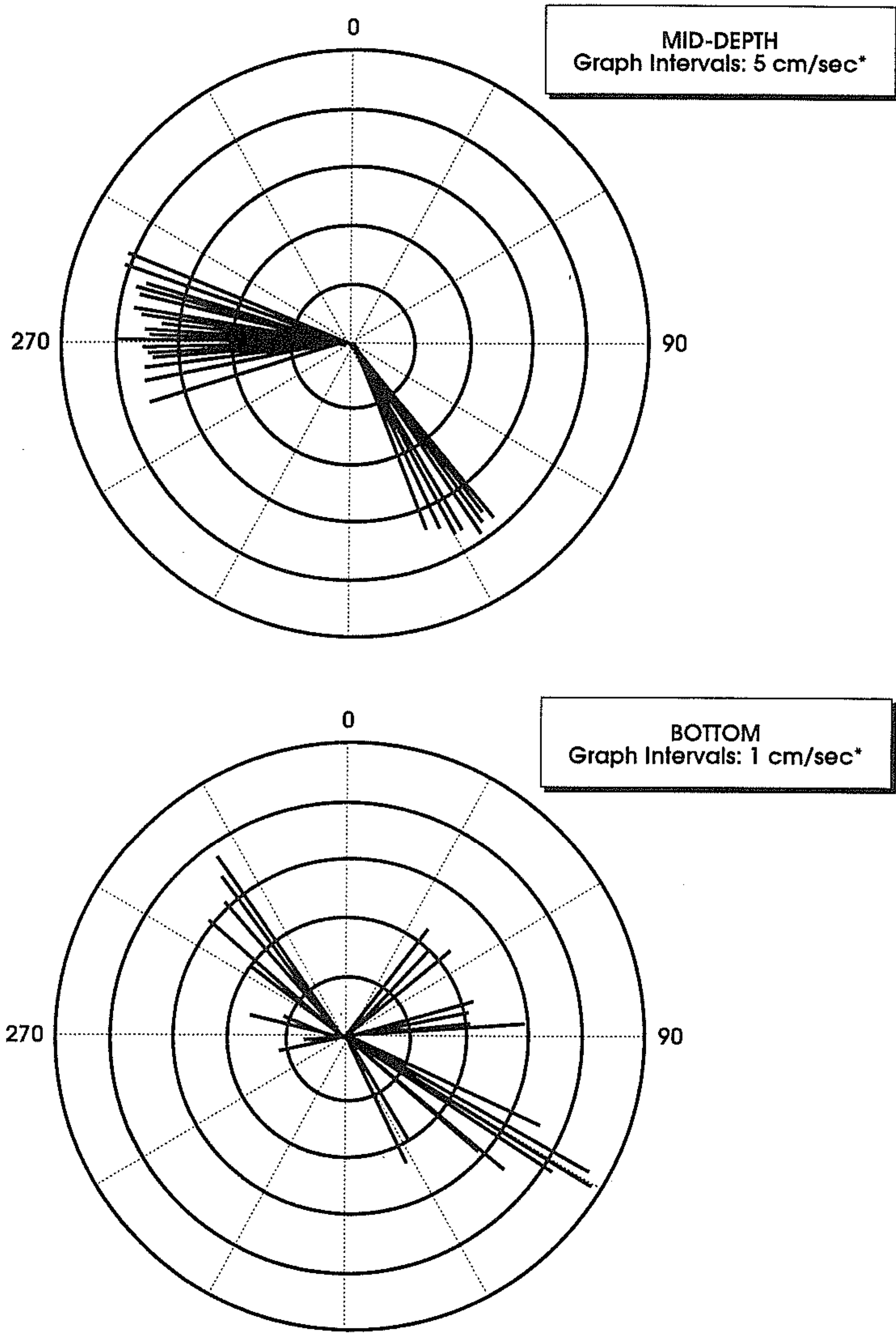
Between 0700 and 1000 on February 17th, the winds were generally light (2 to 8 knots) and from the northeast. Between 1000 and 1045 the winds shifted from the northeast to northwest and remained light. Rain squalls accompanied by strong gusty northeast and northwest winds were observed from 1045 to 1130. Between 1130 and 1400, the winds were generally 5 to 7 knots from the northwest. Rain squalls accompanied by strong gusty northeast to northwest winds again occurred from 1415 to 1500. From 1500 to 1700 the winds were a constant 5 to 10 knots from the northwest.

Table 3-2
Summary of Wind Observations on February 17, 1993

Time (Local)	Wind Speed (Knots)	Direction (magnetic)	Comments
0715	3-5 knots	Northeast	Wind from btwn Rainmaker and Maugaloa Ridge
0800	5-8 knots	Northeast	"
0830	2-5 knots	Northeast	"
0900	5-8 knots	Northeast	"
0945	5-8 knots	Northeast	"
1000	5-8 knots	Northeast	"
1025	3-5 knots	NE to NW	Wind direction variable
1045	5-15 knots	Northwest	Rain squall with gusty NW winds
1145	5-8 knots	Northwest	Wind from direction of Alava Mnt.
1210	5-7 knots	Northwest	"
1254	5-7 knots	Northwest	"
1415	10-15 knots	NW/NE	Rain squalls with winds from NW, then wind changes to NE
1530	5-10 knots	Northwest	Wind from direction of Alava Mnt.
1600	5-10 knots	Northwest	"
1640	5-10 knots	Northwest	"

Current Speed and Direction. The field measurements results of the test dye injection indicated that the plume was trapping at or below 100 feet. Two current meters were deployed to measure the currents near bottom and above the trapping level. Ambient current speed and direction, temperature, conductivity, and depth data were recorded by current meters deployed at a depth of 100 ft. and near-bottom (about 170 feet below the surface or 6 feet above the seabed). The two meters were deployed from 1645 on February 16th to 1715 on February 17th. The complete data record for this 24-hour period is provided in Appendix C to this report. The data presented in this section are limited to the dye study period from 0800 to 1700 on 17 February 1993.

The current meter data shows distinct differences in the speed and direction between the mid-depth and bottom currents. The data are illustrated in Figures 3-2, 3-3, and 3-4. The currents measured at mid-depth (-100 feet) averaged 18.5 cm/sec, while the near-bottom currents (-170 feet) averaged only 2 cm/sec. These differences are best illustrated in

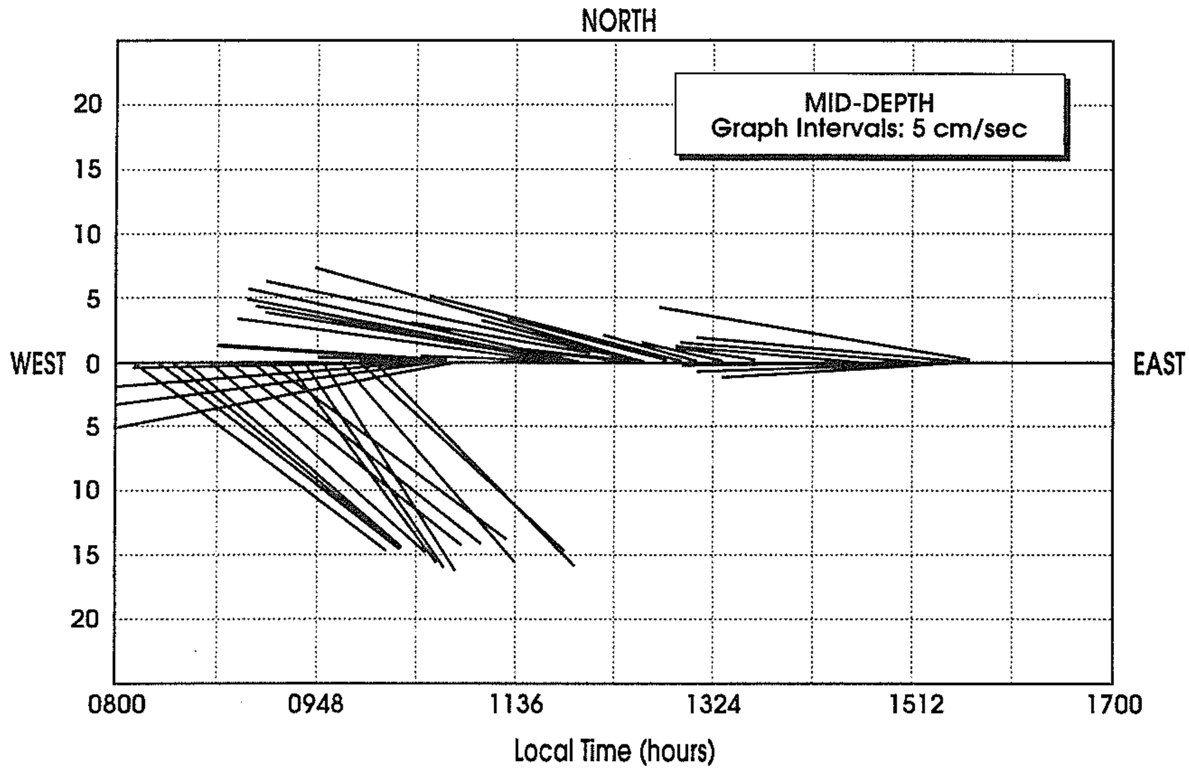


* *Note difference in graph intervals, bottom current speeds are lower than mid-depth. Directions are magnetic.*

FIGURE 3-2

Polar Diagrams of Current Speed and Direction Recorded between 0800 and 1700 at Mid-Depth and Bottom Meters on February 17, 1993

PDX30702.DY.R1 / Samoa Dilution Study / Fig. 3-2 / 6-16-93 / JG/LKW



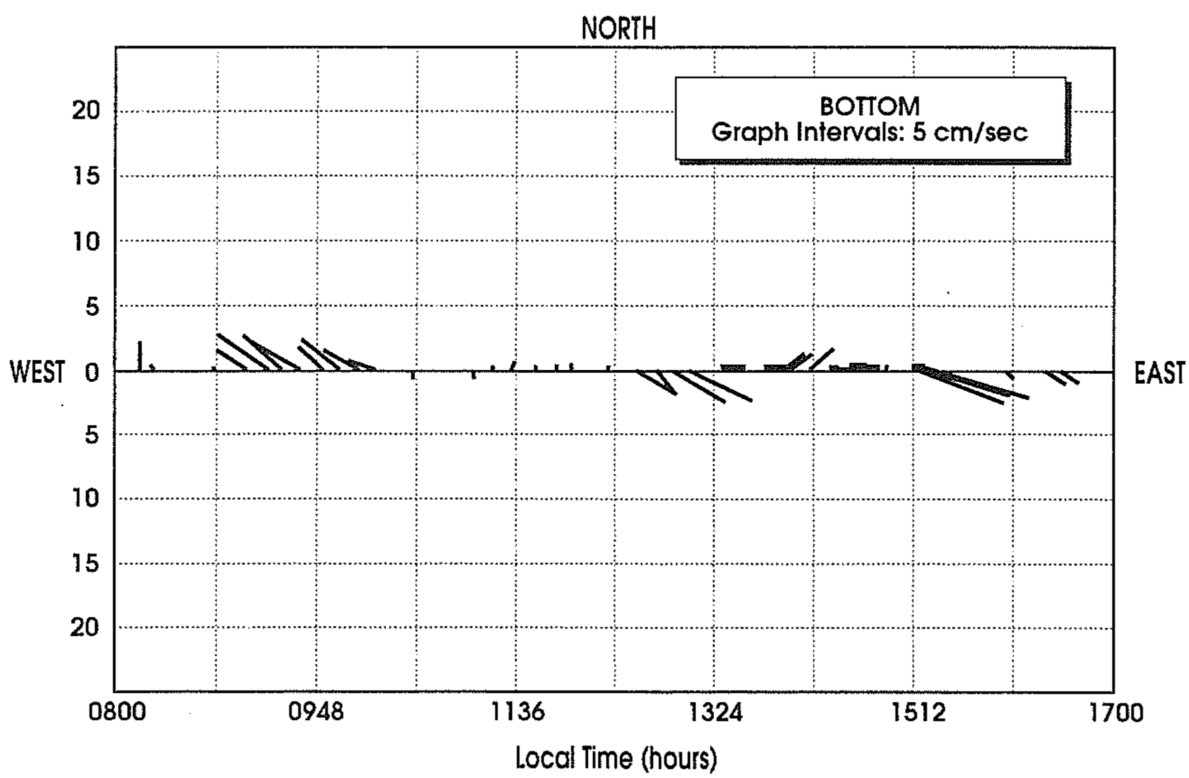
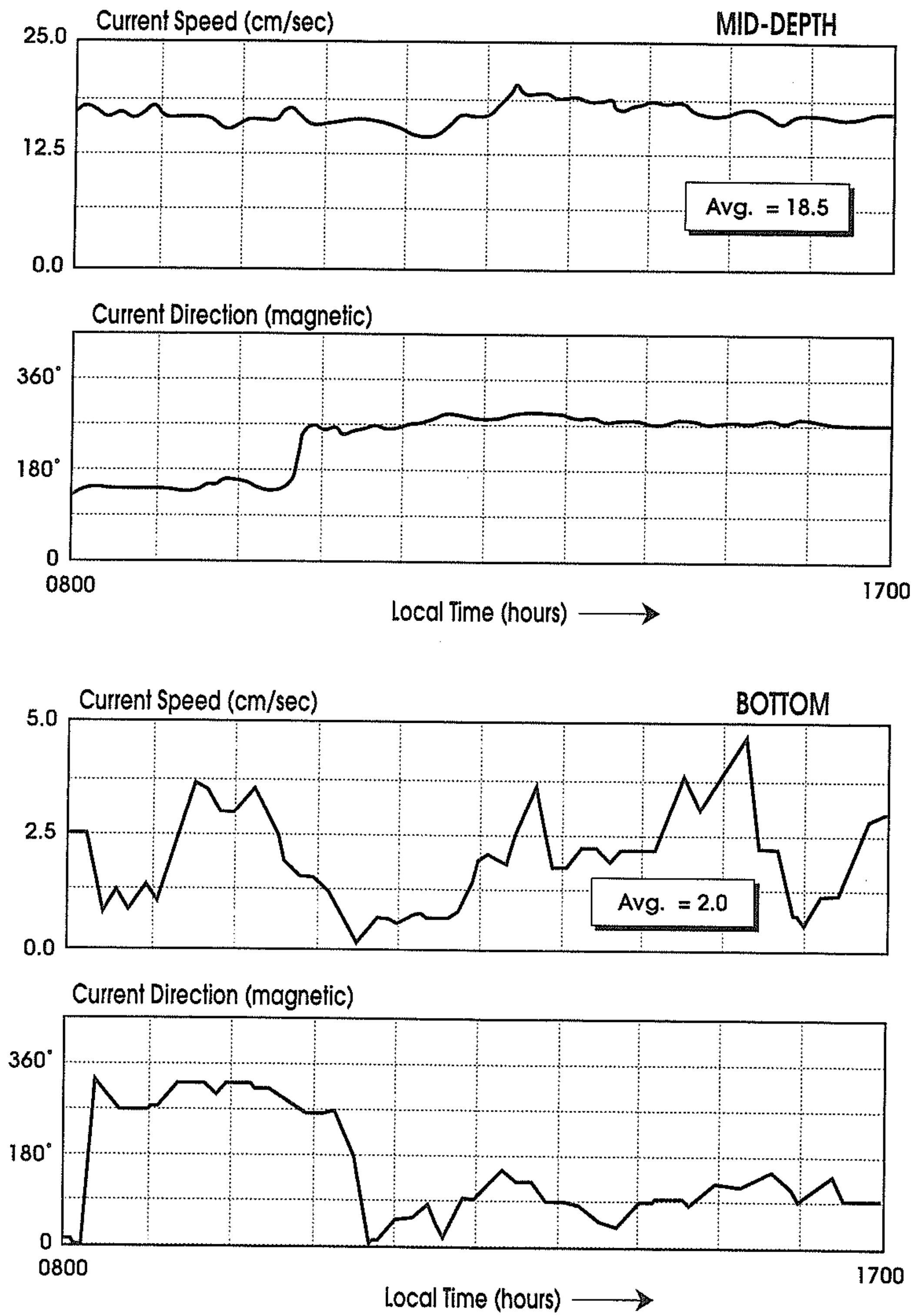


FIGURE 3-3
Straw Plots of Current Speed and Direction at Mid-Depth and Bottom Meters on February 17, 1993

PDX30702.DY.R1 / Samoa Dilution Study / Fig 3-3 / 6-16-93 / JG/LKW



Note: Current speeds graph interval difference, the bottom current speeds are lower than at mid-depth.

FIGURE 3-4

Current Speed and Direction Plots for Mid-Depth and Bottom Currents on February 17, 1993

PDX30702.DY.R1 / Samoa Dilution Study / Fig 3-4 /6-16-93 / JG/LKW

Figures 3-2 and 3-3, which are polar diagrams and time-series straw plots of current speed and direction for both current meters.

The currents recorded at both depths showed two distinct directions during the dilution study (Figure 3-2). The mid-depth currents were directed southwest (150°, mag.) between 0800 and 1100, and between 1100 and 1700 currents were directed to the west (270°, mag.). The near-bottom currents also showed two general directions during the study, heading northwest in the morning and to the southeast in the afternoon (Figure 3-2).

Bottom currents were weakest and variable during the two-hour period from 1100 to 1300. These low current speeds represent the critical receiving water conditions for the trapping and dilution of the wastewater plume. These low near-bottom currents directly effect the plumes from individual diffuser ports and are expected to result in reduced initial dilutions compared to other times during the dye study. Figure 3-4 presents time histories of the current records and illustrates the difference between the two current recordings (note the scale differences).

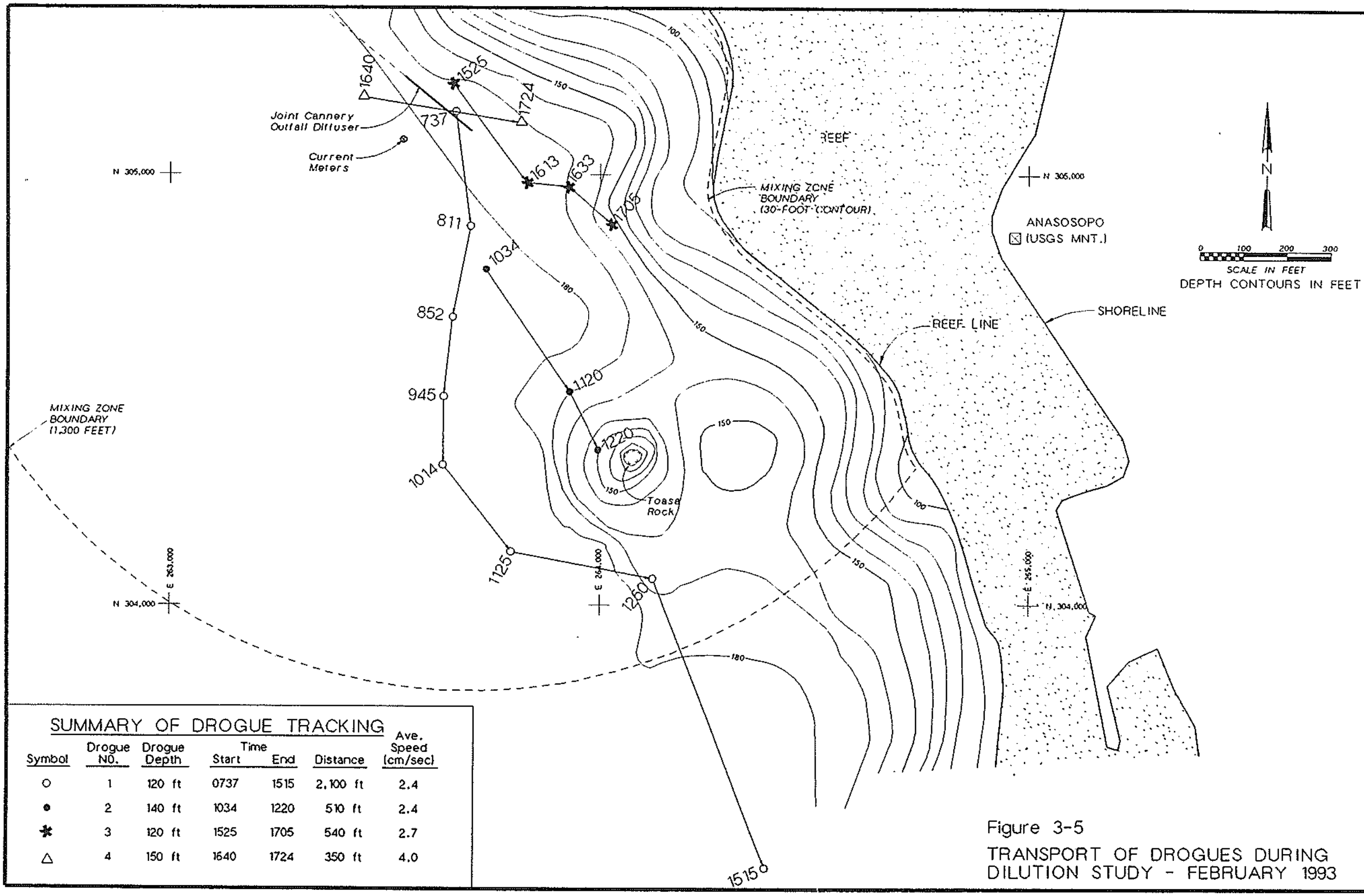
Drogue Trajectories. The subsequent farfield transport of the Joint Cannery Outfall wastefield was measured by tracking drogues deployed near the plume trapping depth. Drogues were deployed near the diffuser and at the depth of highest dye measurements throughout the entire period of the field dye study. The drogue transport direction was used for positioning the sampling vessel to sample for the plume. The drogue tracking results are shown in Figure 3-5. During the dye study the wastefield was transported to the south and southeast, paralleling the depth contours and the reef in outer Pago Pago Harbor. The average speed of travel for the drogues ranged from 2.0 to 4.0 cm/sec., which is consistent with the average current speed for the near-bottom current meter record.

WASTEFIELD DILUTION MEASUREMENTS

The dye study was conducted within the designated mixing zone during a 10-hour period centered on low water. Sampling profiles in the water column were conducted to identify the vertical extent of the wastefield and to locate the depths where the highest dye concentration occurred. On the basis of the profiles, the wastefield was observed to remain trapped below 100 feet and primarily below 120 feet, throughout the entire study period. Transects were conducted to measure the spatial extent of the wastefield at a fixed depth.

Scope of Data Collection. The data collection efforts were directed at measuring the highest ambient dye concentrations, near the diffuser, within, and at the boundary of the mixing zone. More than 300 field dye measurements were recorded during this study. A complete set of dye concentration data with all associated data are provided in Table A-1 in Appendix A. The important aspects and results of each of the profiles and transects done are described below.

Data Processing. Measurements of the initial dye concentrations made during the study (refer to Figure 2-2) were compared with the receiving water dye measurements to



SUMMARY OF DROGUE TRACKING

Symbol	Drogue NO.	Drogue Depth	Time Start	Time End	Distance	Ave. Speed (cm/sec)
○	1	120 ft	0737	1515	2,100 ft	2.4
●	2	140 ft	1034	1220	510 ft	2.4
✱	3	120 ft	1525	1705	540 ft	2.7
△	4	150 ft	1640	1724	350 ft	4.0

Figure 3-5

TRANSPORT OF DROGUES DURING DILUTION STUDY - FEBRUARY 1993 calculate the actual effluent dilution. The initial dye concentrations have been correlated with the corresponding receiving water measurements based on the travel time from the injection site to the outfall diffuser. The travel time from the injection site to the outfall is approximately 1 hour and 10 minutes. The wastefield travel time from the diffuser to the mixing zone boundary is estimated to 6 hours based on the near-bottom current speeds and the travel rate of Drogue No. 1. Field dye concentration measurements are therefore associated with initial dye concentrations that were detected 1.2 to 6 hours prior to field measurement times.

Preliminary Data Collection. Background measurements were taken on February 16th (dye injection test) and February 17th, and these values show a background reading of 0.1 to 0.2 ppb. The low background readings are of the same order as the practical resolution of the fluorometer under field conditions and they have not been subtracted from the dye concentration readings presented in Appendix A and Table 3-3. Therefore, the reported values may over-estimate the actual dye present. The minimum dilution values presented in Tables A-1 (Appendix A) and 3-3 are conservative or under-estimated.

As described in Section 2 above, a dye injection test was conducted on February 16th, prior to the full-day field dilution study on February 17th. The purpose of the test was to determine the water column stratification and the depth that the wastewater plume was rising. The results of the field measurements of the test dye injection indicated that the plume was trapping at depth. Current meters were deployed and the dye study was conducted on the following day using the results of the preliminary test for guidance. Dye concentration Profile Ia and b, recorded during the test injection, clearly illustrates that the wastewater is trapped below 30 meters or 100 feet (Figure 3-6). The highest dye concentrations were measured at 35 to 45 meters (115 to 148 feet) below the surface.

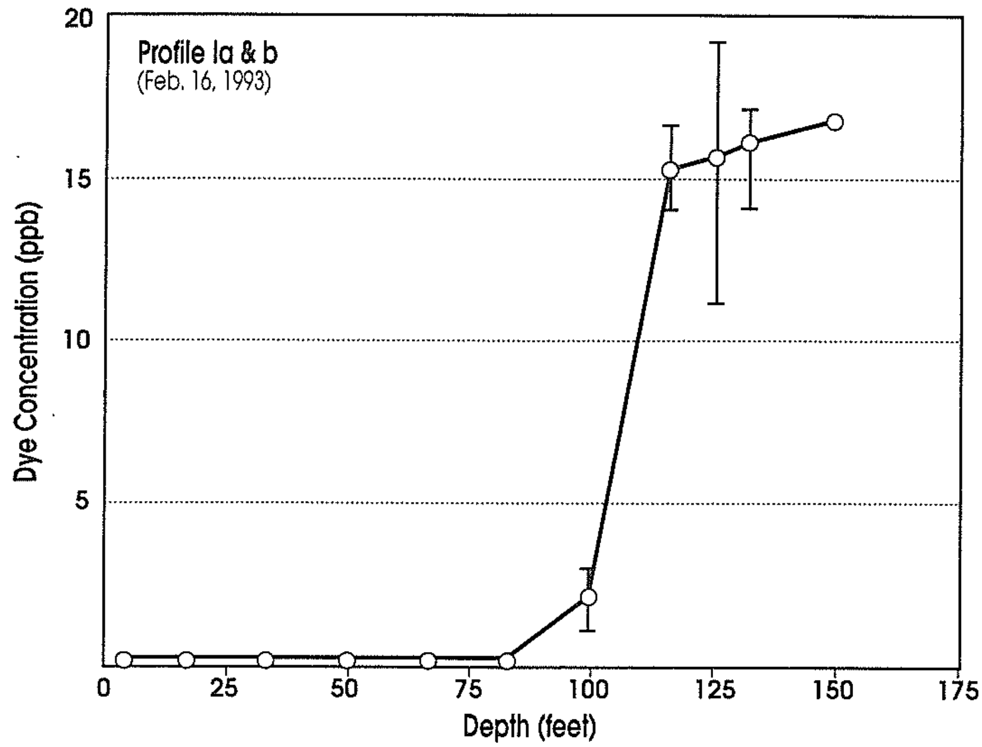
Results of Field Measurements. The detailed locations of the profile and transect sampling stations occupied during the dye injection on February 17th are shown in Figures A-1 through A-12 in Appendix A. Profiles P1, P2, P4, and P6 and Transect T5 were conducted starting at or near the outfall diffuser. Profiles P3, P7, and P8 and Transects T2 and T3 were conducted between the diffuser and the mixing zone boundary. Profiles P5 and Transect T4 were conducted near the mixing zone boundary.

At the start of the field dye measurements on February 17th, a series of water column profile measurements were taken starting from directly over the outfall diffuser and then drifting to the south-southwest (Figures A-1 and A-2 in Appendix A). The wastewater plume was detected from approximately 30 meters (100 feet) down to 50 meters (157 feet) depth, and no dye was detected above 27 meters (90 feet). Figure 3-6 shows a example plot of the detected dye concentrations with depth. A summary of minimum dilutions detected during the dilution study field data collected is provided in Table 3-3. The following points summarize the results of the dye measurements on 17 February 1993:

- Figure 3-7 provides a plan view of the wastefield sampling sites on Profile P2 started at 0804. The values presented are the wastewater dilutions, and they are described by sampling depth. These results indicate that the submerged plume and wastefield were transported to the south-southeast.

Table 3-3
Minimum Effluent Dilutions Measured on 17 February 1993

Station No. (P = profile, T = Transect) and Location	Current Speed and Direction at Depth (cm/sec) (magnetic)		Time (Local)	Depth (ft)	Minimum Dilution	Approximate Distance from Diffuser (feet)
	100 ft	170 ft				
P1 - Near Diffuser	18.4 134°	3.5 347°	0752	130	370	275
P2 - Near Diffuser	19.3 140°	2.6 0°	0824	119	234	20
T1 - South Mixing Zone Boundary	18.3 141°	2.4 318°	0915	60 to 115	>32,000 (Not Detected)	1300
P3 - Near Toasa Rock Buoy	17.7 158°	3.1 328°	0945	75 to 145	>34,000 (Not Detected)	600
P4 - At Diffuser Site	18.0 145°	3.0 318°	0959	144	123	20
T2 - Near Diffuser to South	18.1 164°	1.6 284°	1031	155	402	150
P5 - South Mixing Zone Boundary	16.3 276°	0.7 56°	1146	159	6,786	1250
T3 - Near Diffuser	17.9 290°	0.6 18°	1220	142	227	275
T4 - SE of Toasa Rock (near Mixing Zone Boundary)	20.5 289°	3.1 130°	1254	97 to 163	>32,000 (Not Detected)	1200
P6 - SSE of Diffuser	19.8 271°	2.3 75°	1419	126	264	100
P7 - SSE of Diffuser	17.9 277°	2.3 128°	1536	144	327	100
P8 - SE of Diffuser near Reef	17.9 276°	0.6 90°	1612	160	892	350
T5 - NNE Side of Diffuser	18.4 271°	2.8 90°	1648	143	403	100



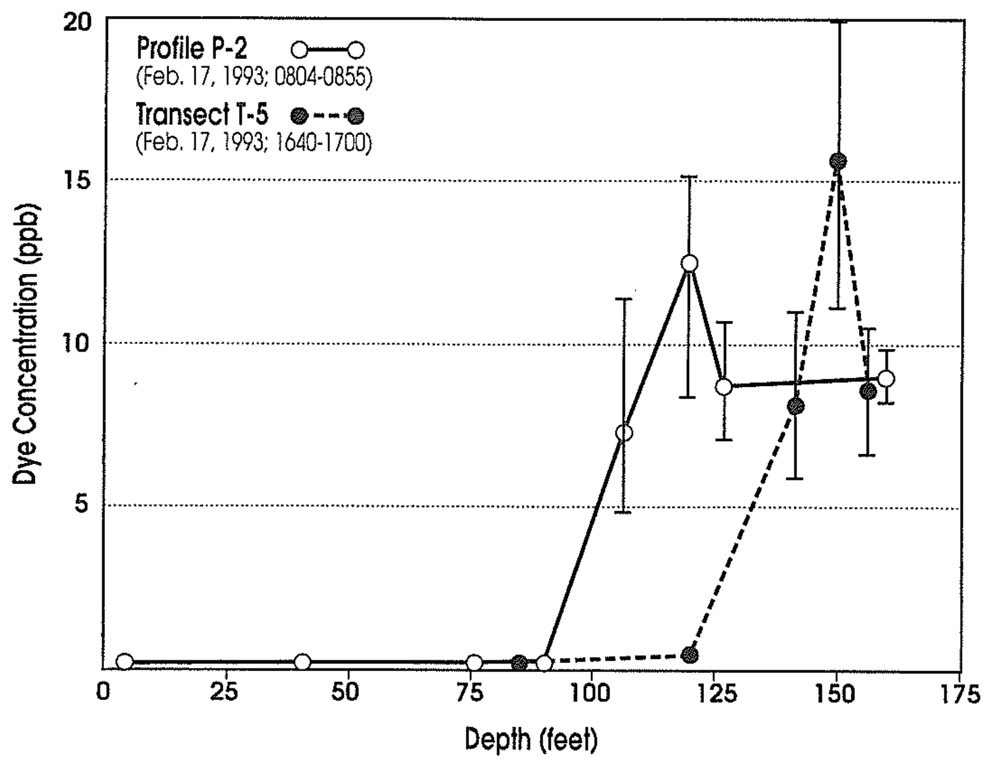


FIGURE 3-6
Plots of Dye Concentrations for Typical Water Column Profiles Conducted February 16th & 17th, 1993

PDX30702.DY.R1 / Samoa Dilution Study / Fig. 3-6 / 6-17-93 / JG/LKW

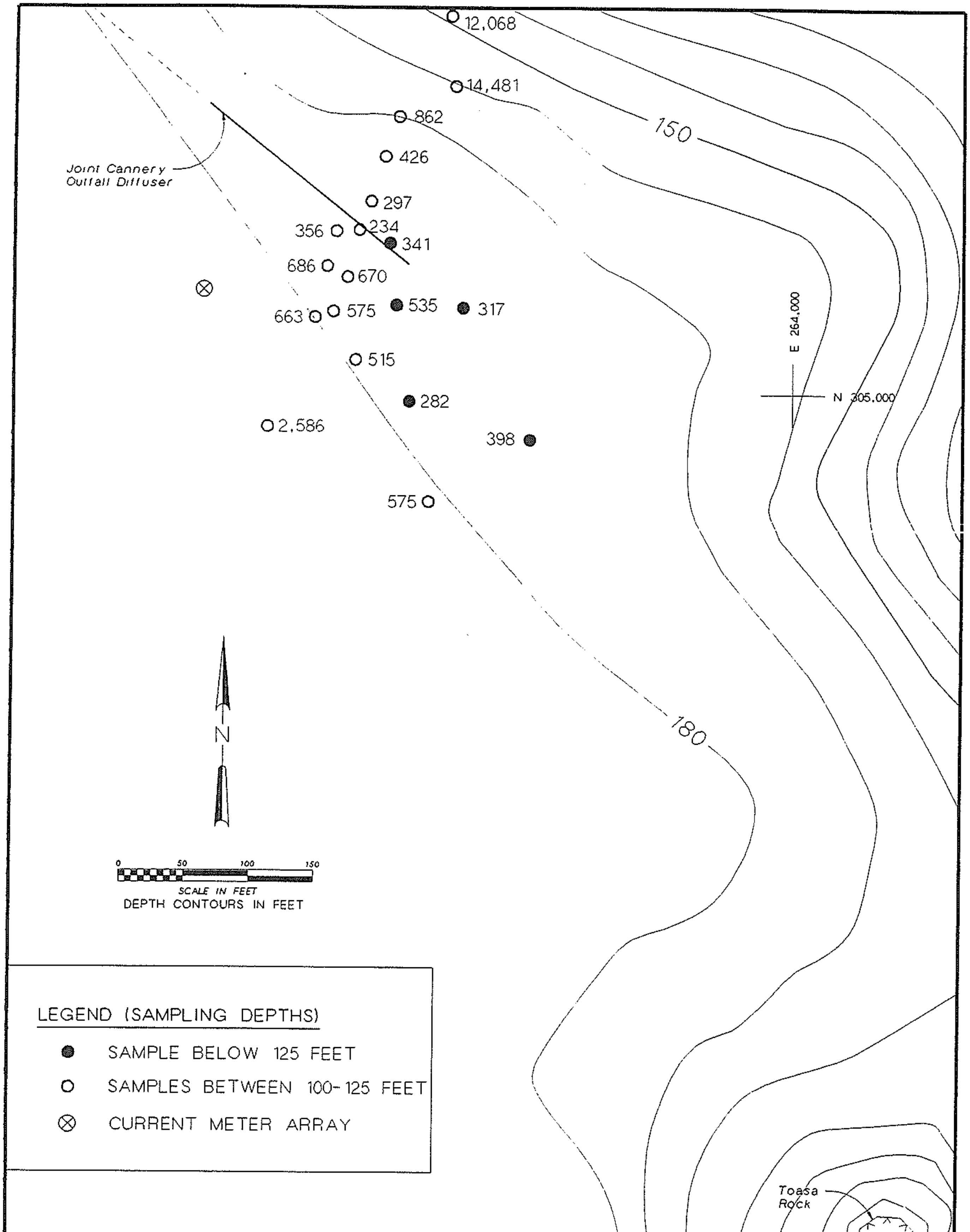


Figure 3-7
DILUTION MEASUREMENTS ON PROFILE P-2;
FEBRUARY 17, 1993; 0804-0855

The 4 ports on the diffuser face in alternating directions and the plume is detected on both sides of the diffuser. Essentially no dye or wastewater was detected at sampling sites 150 feet northeast of the diffuser, towards the reef face.

- At 0908, Transect T-1 was conducted at a depth of 35 meters (115 feet) along the south mixing zone boundary, and no dye was detected. Profiles P3 and P4 were conducted south of the diffuser, and the wastefield was detected at a minimum measured dilution of 833:1 approximately 650 feet south of the diffuser (Figure 3-8).

- The lowest dilution (123:1) recorded during the study was measured on Profile P4 while situated directly over the outfall diffuser. This measurement appears to be taken directly in a plume prior to the completion of initial dilution. The diffuser configuration (four 5-inch ports spaced 50 feet apart on alternating sides of the diffuser) and the discharge depth (176 feet) results functionally in four separate single port discharges. Merging of the four plumes does not occur immediately, which enhances the initial dilutions achieved. The 123:1 measurement is believed to have been within one of these individual plumes.

- Between 1025 and 1048, Transect T-2 was conducted at a depth of 47 meters (155 feet) starting from the diffuser and ending near Toasa Rock (Figure A-5 in Appendix A). This transect measured dilutions ranging between 722:1 and 1177:1, at distances of 500 to 600 feet south of the diffuser. Transect T-3 was conducted at similar depths, and located closer to the reef to the east (Figure A-7 in Appendix A). The minimum wastewater dilution measurements recorded on Transect T-3 are plotted in plan view in Figure 3-9. These measurements show the wastefield was being transported at depth, directly to the southeast and parallel with the reef. Transect T-3 was ended because the path was headed directly for Toasa Rock. The vessel was repositioned on the southeast side of Toasa Rock and Transect T-4 was conducted in an effort to reacquire the wastefield, however no dye was detected on Transect T-4.

- Starting at 1415 Profiles P6, P7, and P8 were conducted as drifting profiles from the diffuser site heading to the south-southeast parallel with the reef (Figures A-9, A-10, and A-11 in Appendix A). The minimum wastewater dilution measurements recorded on Profiles P7 and P8 are plotted in plan view in Figure 3-10. These measurements indicate that the wastefield continued to be transported at depth, to the south-southeast, and parallel with the reef.

- Between 1640 and 1700, Transect T-5 was conducted at a depth of 45 meter (150 feet), starting from the diffuser and heading east towards the reef (Figure A-12 in Appendix A). This transect measured dilutions ranging

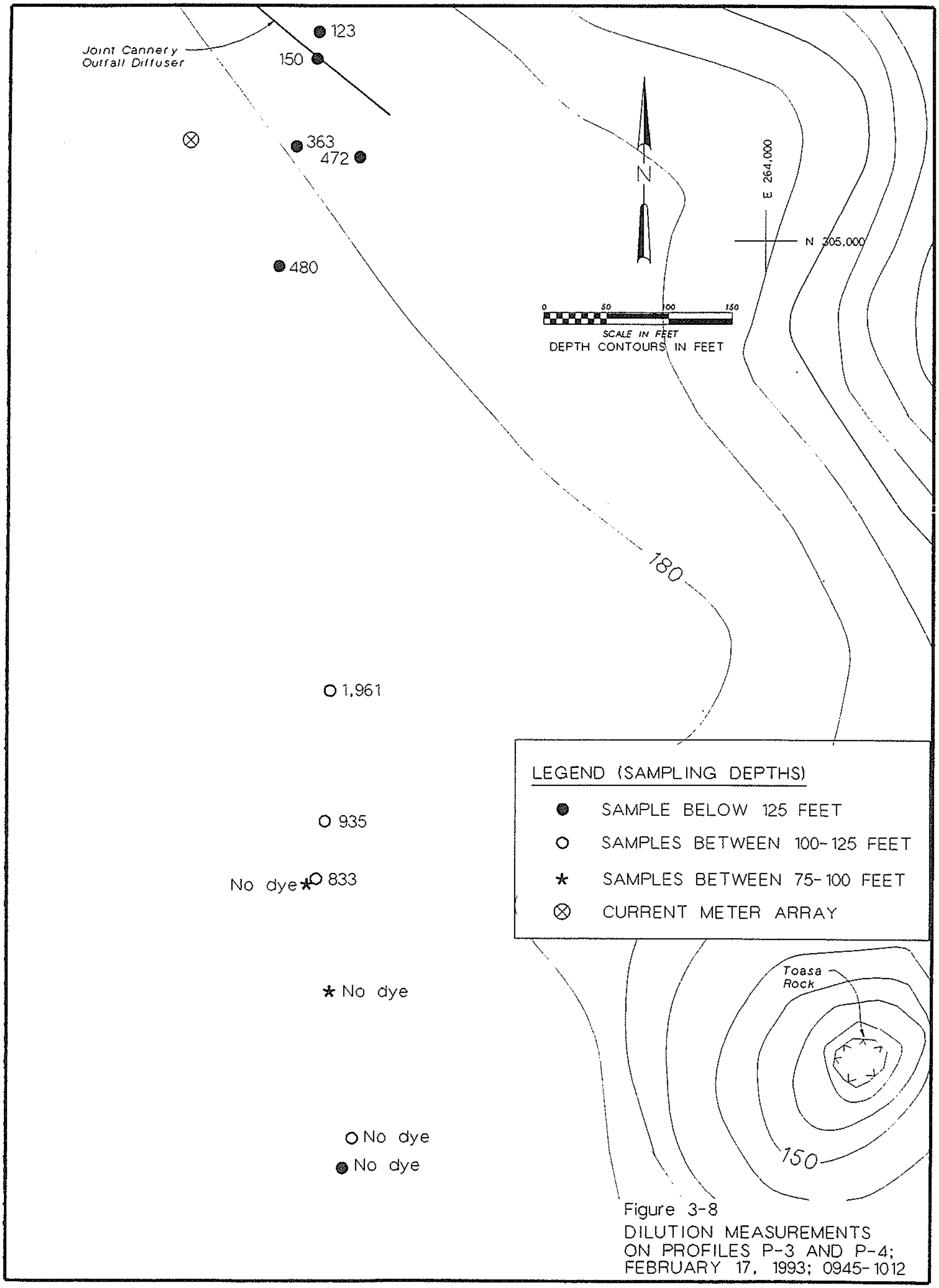


Figure 3-8
DILUTION MEASUREMENTS ON PROFILES P-3 AND P-4; FEBRUARY 17, 1993; 0945-1012

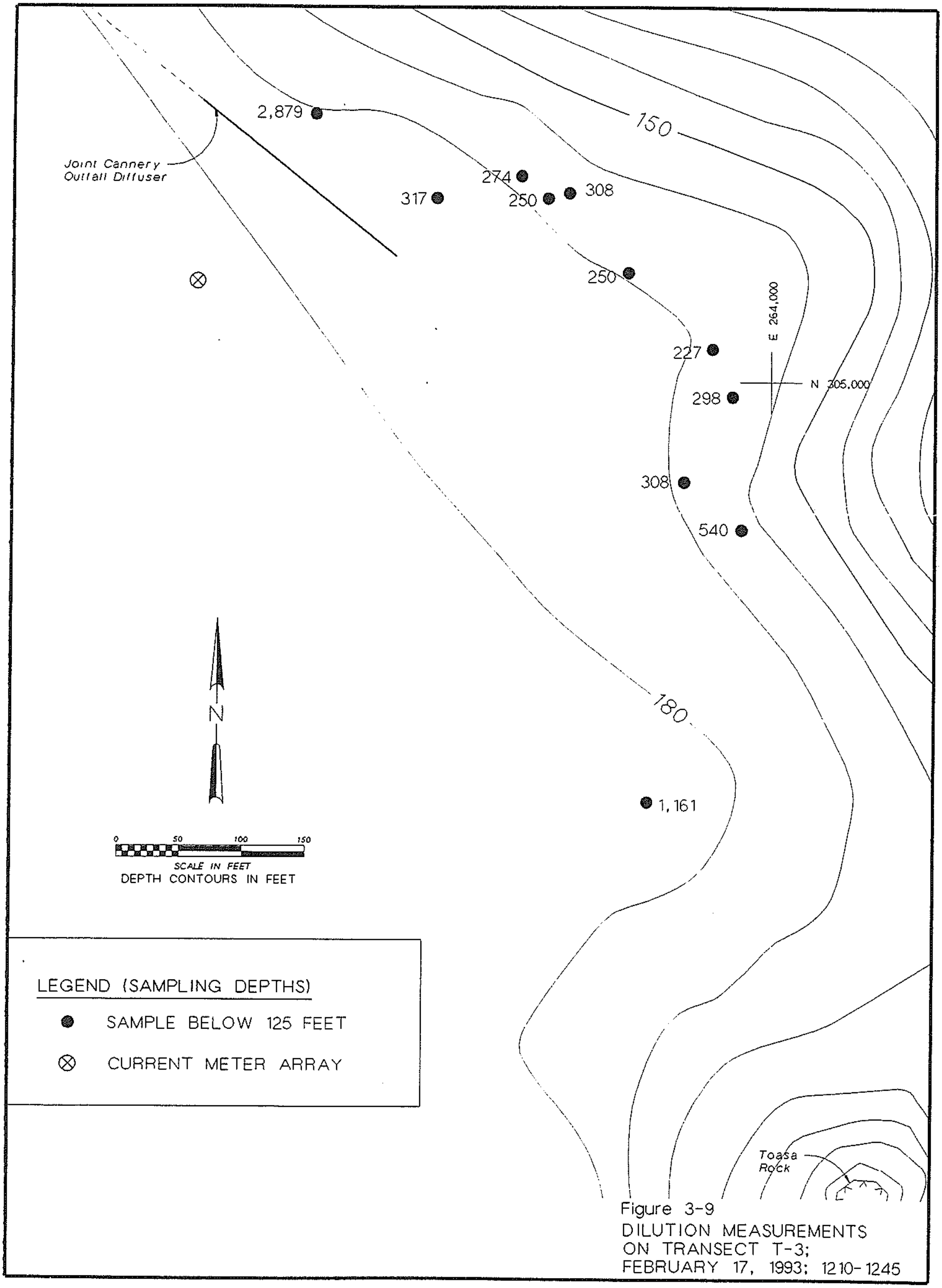


Figure 3-9
DILUTION MEASUREMENTS
ON TRANSECT T-3;
FEBRUARY 17, 1993; 1210-1245

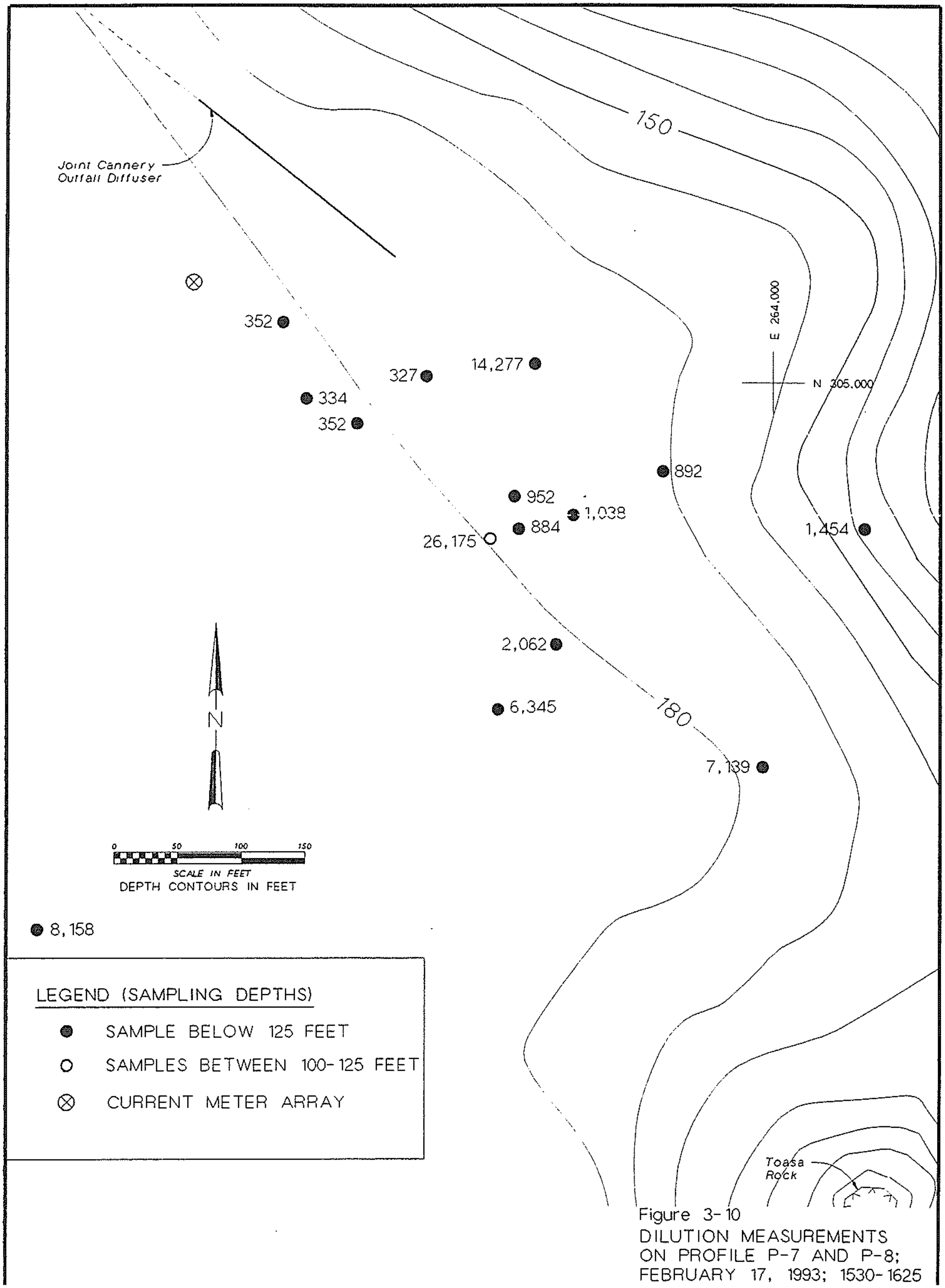


Figure 3-10
DILUTION MEASUREMENTS
ON PROFILE P-7 AND P-8;
FEBRUARY 17, 1993; 1530-1625

between 512:1 and 865:1, at distances of approximately 200 feet east of the diffuser.

The results summarized above, and provided in more detail in Appendix A, provide sufficient data to evaluate the diffuser performance during the non-tradewind oceanographic season. The data can also be used to demonstrate the reliability of the initial and subsequent dilution model predictions. Conclusions concerning diffuser performance and mixing zone adequacy as well as recommendations for the second dye study are presented in Section 4 below.

Section 4

CONCLUSIONS AND RECOMMENDATIONS

The primary objective of the dye study was to provide direct measurements of the effluent plume. This is a key element of the NPDES permit conditions. The overall goal of the permit conditions is to verify compliance with the American Samoa Water Quality Standards (ASWQS). Information from the dye studies can be used to verify the calculations, assumptions, and model predictions used to develop the zone of mixing (ZOM). Complete verification includes consideration of the wastefield transport model predictions of ambient concentrations of effluent constituents throughout the harbor. This complete verification will not be done until after the second dye study is complete, monitoring results have been provided by American Samoa EPA, and the model verification condition of the NPDES permits is accomplished.

The results of the first dye study can be used to examine compliance with the ASWQS in a limited fashion and to validate predicted diffuser performance. Conclusions based on the data collection and analysis of the dye study and recommendations regarding the second scheduled dye study and the subsequent model verification study are discussed below.

CONCLUSIONS

This section provides conclusions based on the results of the February 1993 field dye study in three areas: [1] comparison of field measurements with previous model predictions of diffuser performance and initial dilution achieved, [2] comparison of field measurements with previous model predictions of subsequent dilution, and [3] comparison of field measurements with required dilution at the mixing zone boundary. In addition the data collected have been used to assess many of the assumptions made about the physical environmental parameters in the harbor, harbor circulation and mixing processes, and the transport of the Joint Cannery Outfall wastefield. These assumptions were used in the development of the outfall location and mixing zone geometry.

Oceanographic Conditions

The important physical conditions in the harbor include current speed at the diffuser, overall circulation in the outer harbor in and adjacent to the ZOM, and the density gradients in the harbor. During the outfall feasibility and ZOM studies conservative assumptions were used to develop the outfall location and ZOM. Data collected during the dye study generally confirm the assumptions and conclusions used, and safety factors employed, for development of the outfall location and mixing zone geometry (see CH2M HILL, 1991a and 1991b).

Current Speeds. Initial dilution models assumed zero current speeds at the diffuser as a conservative approach (lower dilutions than actually expected). Actual current speeds, under non-tradewind conditions near the seabed in the area of the diffuser were found to be about 2 cm/sec. The zero current assumption appears to be conservative as expected.

The currents assumed for the subsequent dilution models were low (0.05 cm/sec). Actual currents measured at mid-depth, at a fixed location near the diffuser, were found to be 15 to 20 cm/sec at the depth of the plume in the area of the diffuser. The drogue trajectories indicate currents at the depth of the plume, over a wider area, were on the order of 2.5 to 4 cm/sec. The mid-depth current meter appears to have been located in an area of relatively fast currents. Current speeds seem to decrease significantly with depth and towards the reef wall.

The currents assumed for subsequent dilution appear to have been low. The low current assumption for the subsequent dilution model was not necessarily conservative. However, the effect of current is far more pronounced on initial dilution than on subsequent dilution. The overall currents measured match the assumptions used in the modeling in general and the modelling appears to have been conservative, resulting in underpredicted values for dilution.

Current Directions. Current direction (and speed) show no correlation with tides, as expected. This can be seen by visually comparing Figures 3-1 (tide) with Figures 3-3 and 3-4 (currents). A more comprehensive comparison will be done during the model verification study. The currents do, however, show a remarkable correlation with wind direction. The wind shifted from the northeast to northwest at about 1030 (Table 3-2). The current direction for the mid-depth station shifted at the same time and the direction at the deep station shifted with about a one hour lag (Figure 3-4). This is precisely the behavior expect of a wind dominated system with the geometry of Pago Pago Harbor. The assumption of a generally wind driven system is further confirmed by these data. The observed current directions are consistent with expected behavior as well.

Circulation Patterns. During the feasibility study no preferential direction was assumed for the circulation in the vicinity of the diffuser for generating model predictions of effluent concentrations throughout the harbor. Current patterns were examined in the context of diffuser siting. Based on available data it appeared that the general circulation would result in a net seaward advective flux of material, at depth, in the vicinity of the selected diffuser location.

The wastefield transport modeling analysis was carried out based on known loadings and measured concentrations of total nitrogen and total phosphorous throughout the harbor. It was further predicted that the effluent plume would be trapped at the depths where the net flux was outward. Since the wastefield transport model was based on a depth averages source, the model did not account for a biased seaward transport and was therefore considered conservative (prediction of higher concentrations than actually expected).

The drogue trajectories indicate a net outward flux at the trapping level of the plumes. For non-tradewind conditions the model assumptions are conservative, as expected. Although there appears to be a difference between the current meter records and the drogue tracts, they are actually in good agreement. It must be remembered that the current meters are recording flows at fixed points and do not represent currents at other locations. The further away from the meter station the drogues are located the less agreement there should be between them and the meter data. This is particularly true as the reef wall is approach because the reef will strongly influence the direction of the current. Therefore, some inconsistency between the meters and the drogues is not unexpected.

Even with the differences described above there appears to be good consistency between the current meters and the drogue trajectories. During northeast winds the mid-depth current meter appears to be in the same layer of water as the drogues (and the trapped plume). During the northwest winds the mid-depth meter is in an intermediate layer of water, moving as a return flow generally opposite to the wind direction under the influence of the adjacent reef wall. Under these conditions the drogues appear to be in a deeper layer more associated with the near bottom current meter. These kinds of changes in circulation, and layers of flow, were expected and described roughly in the feasibility study (CH2M HILL, 1991a). The plume trapping in the seaward flowing layers under both conditions is considerably more conservative than the basis used for the model predictions.

Density Stratification. It was previously assumed, based on available data, that the non-tradewind conditions would result in weaker density gradients than the trade wind conditions. Stronger gradients tend to inhibit initial dilution by forcing the plume to trap at deep levels. This limits the available time the initial dilution process can continue. Therefore stronger gradients were generally used as a conservative approach to initial dilution calculations.

Weaker gradients are more likely to allow the plume to surface, which is not a desirable feature. The gradient observed during the non-tradewind conditions was approximately the strength assumed for the tradewind (strong gradient) conditions with a change in Sigma-t of about 0.4 between surface and bottom (see CH2M HILL, 1991b and Table 3-1 above). This indicates that the plume should stay trapped below the surface even in non-tradewind conditions. The initial dilution predictions will still be conservative because they are also based on zero current speed.

Diffuser Performance

The diffuser appears to be performing as expected. Model runs of the diffuser under actual field conditions will not be done until the model verification study. However, based on the model runs done previously (CH2M HILL, 1991a and 1991b) the initial dilution and trapping depth appear consistent with predictions for similar environment parameter values.

Trapping depth appears to be somewhat deeper, probably about 20 to 40 feet, than expected. Initial dilutions appear to be as good or better than the predicted values under similar conditions. The model predictions are based on flux average dilution across the plume and many of the dye study measurements are probably representative of centerline dilutions. Examination of the approximate plume averages using the data in Table 3-4 indicates that the model predictions were, as expected, conservative but within a factor of less than 2.

The lowest dilutions measured were over 120:1 directly over the diffuser. These data appears to indicate this is a minimum (centerline) value and within the plume just as it exits the diffuser. Although this does not rigorously confirm the details of the plume concentration distribution, it does provide strong evidence that the model predictions can be used with confidence to define toxicity mixing zones as was the basis for un-ionized ammonia described in the NPDES permits. The general predictive ability of the initial dilution model used appears to be reliable; more detailed verification will be done during the model verification study.

Subsequent Dilution

Subsequent dilution of the effluent plume, following the rapid initial dilution, appears to be higher than model predictions. Figure 4-1 shows all dilution measurements below 10,000:1 as a function of distance from the outfall. This data set indicates a subsequent dilution along the plume centerline of on the order of 20:1 between the end of initial dilution and the mixing zone boundary. This is about what the model predicts for very low current speeds. Model predications for higher current speeds, as observed in the field, would be less than this. Therefore, the model predictions appear to be conservative.

Compliance at the Mixing Zone Boundary

Figure 4-1 was prepared from the data collected during the dye study to examine, on a preliminary basis, the overall validity of the model predictions used to determine the ZOM and implications for compliance with ASWQS at the ZOM boundary,. Since actual concentrations of constituents are not considered in this study, quantitative compliance criteria is not assessed. The modeling done during the feasibility study (CH2M HILL, 1991a) predicted that water quality standards would be met throughout the harbor if a dilution of approximately 1200:1 could be achieved at a mixing zone boundary set at 1300 feet from the diffuser or the 30-foot depth contour whichever was closer. The diffuser and ZOM location and geometry were designed to meet these criteria. The results of the study indicate that the diffuser is performing as planned and the ZOM location and geometry are meeting the objectives as follows:

- No dye was detected at the 30 foot depth contour. The plume centerline was typically trapped 100 feet or more below the surface.

- The data indicate that a dilution of 1200 was achieved at less than 800 feet from the diffuser.

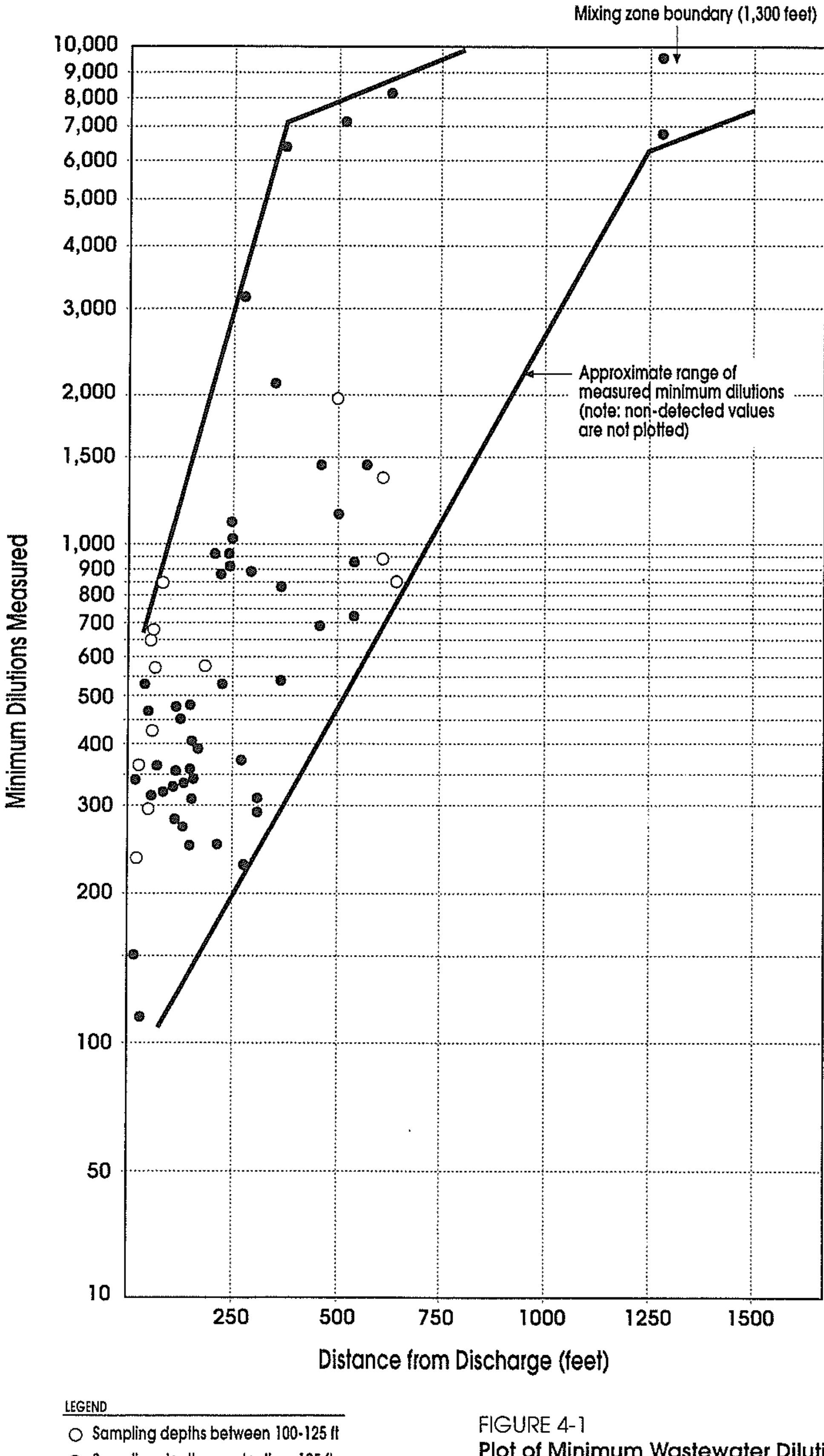


FIGURE 4-1

Plot of Minimum Wastewater Dilutions Measured at Distances from the Diffuser to the Mixing Zone Boundary

PDX30702.DY.R1 / Samoa Dilution Study / Fig. 4-1 / 6-17-93 / JG/LKW

- The data indicate that minimum dilutions of over 4000 and less than 7000 are expected at the mixing zone boundary.

The dilutions measured were somewhat higher than anticipated. The plumes from the diffuser were very difficult to track past about 200 meters. Therefore, only a few measurements of dilution at the mixing zone boundary were made. Most attempts to measure dye at the mixing zone boundary resulted in no detectable dye concentrations (corresponding to dilutions of > 25,000:1). The second dye study, in August/September 1993, will attempt to find and measure the plume at distances near the mixing zone boundary.

The conditions (current speed, density profile, flow, etc.) are not the same as "worst case" conditions assumed during the initial modeling. However, it appears that the EPA initial and subsequent dilution models used during the feasibility and design process are conservative by a factor of about 1.5 to 2. The model predictions for plume behavior will be verified using measured conditions and dilution during the modeling verification task to be done following the second dye study.

The dye study results confirm the diffuser performance and the criteria on which the ZOM was based. Compliance with water quality standards, for a particular level of diffuser performance, was based on predictions made using our wastefield transport model. Final confirmation of compliance with water quality standards throughout the harbor is based on water quality monitoring results being conducted by ASEPA. The wastefield transport model predictions will be subject to verification, based on these monitoring results, after the second dye study is completed and monitoring data are received.

RECOMMENDATIONS

The non-tradewind dye study was successfully executed and provided sufficient data to meet the study objectives. It was very difficult to track the effluent plume to the ZOM boundary. This was an indication of the good diffuser performance, good mixing characteristics in the area of the ZOM, and rapid wastefield dispersion. It would be useful, for purposes of model verification, to obtain more information at a distances between 600 and 1300 feet from the diffuser. This would fill in the area on Figure 4-1 to the right of the concentration of data points. To achieve this it is recommended that higher dye concentrations be injected and the second dye study concentrate on the farfield region close to the ZOM boundary.

Other than attempting to detect dye at greater distances no additional substantial changes are suggested for the dye study to be done during tradewind conditions. Other recommendations of a minor nature include: acquisition of additional background density profiles before, during, and after the dye measurements, additional and more comprehensive wind data collection, and development of a method to better estimate StarKist effluent flow rates out of the surge tank. These items will be included, as appropriate, in the revised study plan to be submitted for review to USEPA and ASEPA.

Section 5

REFERENCES

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APPENDIX A

DILUTION STUDY FIELD DATA

Table A-1
Field Measurements Collected February 17, 1993
Joint Cannery Dilution Study

Pt No.	Station	Sampling Location	Tide Stage	Mid-depth Current Speed and Direction	Bottom Current Speed and Direction	Time	Sampling Depth (feet)	Navigation Distances (m) Code 1	Code 4	Temp. (deg.F)	Salinity (ppt)	Measured Dye Concen. (ppb)	Temperature Corrected Reading (ppb)	Initial Dye Concen. (ppb)	Minimum Dilution Ratio (Initial/Field Measurement)	Comments
1	P-1	Diffuser Site	Ebbing	18.4 cm/sec	3.5 cm/sec	0723	114	1339	1704	84.19	35.16	0.2	0.2	3000	12979	NE of Diffuser 300 ft.
2		(Drifting N to S)		134 deg.	347 deg.	0724	114	1363	1687	84.14	35.10	0.3	0.3	3000	11126	NE of Diffuser 200 ft.
3						0725		1370	1688	84.14		1.1	1.1	3000	2729	AT Diffuser
						0726	116	1370	1688	84.15	35.14	1.5	1.6	3000	1886	At Diffuser
4						0727	116	1391	1683	84.15		2.1	2.2	3000	1381	50 ft SW of Diffuser
5						0728	116	1404	1684	84.11	35.15	3.4	3.5	3000	868	
6						0728	116	1413	1689	84.15		2.1	2.1	3000	1407	100 ft SW of Diffuser
7						0729	116	1425	1687	84.15		0.8	0.8	3000	3562	175 ft SW of Diffuser
8						0731	116	1441	1681	84.13	35.16	0.5	0.5	3000	5472	
9						0733	117	1462	1679	84.13		0.2	0.2	3000	14501	Out of Plume
10						0745	134	1372	1712	83.96	35.10	4.8	4.8	3000	632	50 ft
						0746	133	1372	1712	83.92	35.12	6.5	6.4	3000	471	At Buoy Line
11						0747	131	1396	1711	83.92	35.16	5.7	5.6	3000	537	50 ft Past Buoy Line
12						0747	133	1405	1707	83.92		8.1	7.9	3000	378	
13						0748	133	1418	1713	83.92	35.09	7.1	6.9	3000	434	200 ft past buoys
						0750	133	1418	1713	83.98	35.08	7.8	7.8	3000	387	
14						0752	130	1454	1699	83.96	35.08	8.2	8.1	3000	370	300 ft SW of Buoy Line
15						0754	133	1480	1699	84.11	35.05	3.5	3.6	3000	833	400 ft SW of Buoy Line
16						0755	131	1493	1705	84.04	35.07	0.2	0.2	3000	13495	Out of Plume
														3000		
	P-2	Diffuser Site	Ebbing	19.3 cm/sec	2.6 cm/sec	0804	157			83.87		2.8	2.7	3000	1108	
				140 deg.	0 deg.	0804	157			83.87		3.3	3.2	3000	940	
17						0805	157	1392	1713	83.87	35.32	4.9	4.7	3000	633	
						0805	157			83.87	35.30	9.1	8.8	3000	341	
18						0806	157	1406	1717	83.87	35.30	3.5	3.4	3000	887	at Buoy Line
						0806	142			83.87	35.30	5.8	5.6	3000	535	25 ft Past Line
19						0807	142	1413	1732	83.87	35.30	4.4	4.3	3000	705	
						0808	127			83.87	35.30	9.1	8.8	3000	340	
						0808	127			83.87	35.30	9.8	9.5	3000	317	
20						0809	125	1428	1723	83.87		11.0	10.6	3000	282	
						0809	125			83.87		7.3	7.1	3000	425	
21						0809	125	1446	1742	83.87		7.8	7.5	3000	398	
22						0810	115	1452	1732	83.87		5.4	5.2	3000	575	
23						0810	117	1456	1731	83.87		1.3	1.3	3000	2387	
24						0819	118	1365	1724	83.87		0.3	0.2	3500	14481	100 ft NE of Site

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Pt No.	Station	Sampling Location	Tide Stage	Mid-depth Current Speed and Direction	Bottom Current Speed and Direction	Time	Sampling Depth (feet)	Navigation Distances (m) Code 1	Code 4	Temp. (deg.F)	Salinity (ppt)	Measured Dye Concen. (ppb)	Temperature Corrected Reading (ppb)	Initial Dye Concen. (ppb)	Minimum Dilution Ratio (Initial/Field Measurement)	Comments
	P-2	Diffuser Site				0819	119			83.87		4.6	4.5	3500	782	Buoy Line
25						0820	119	1365	1711	83.87		3.1	3.0	3500	1168	
						0820	119	1366	1710	83.87		4.2	4.1	3500	862	
26						0821	119	1374	1739	83.87		5.2	5.0	3500	696	50 ft NE of Line
						0822	119	1376	1707	83.87		8.5	8.2	3500	426	
27						0823	119	1381	1707	83.87		12.2	11.8	3500	297	
28						0824	119	1386	1705	83.87		14.9	14.4	3500	243	
						0824	119			83.87		15.5	15.0	3500	234	
						0825	119	1388	1705	83.87		4.4	4.3	3500	823	
29						0825	119	1395	1702	83.87		5.4	5.2	3500	670	
30						0826	119	1397	1704	83.87		6.3	6.1	3500	575	
31						0827	119	1401	1702	83.87		7.0	6.8	3500	515	At Buoy Line
						0828	102	1414	1709	83.87		2.3	2.2	3500	1595	
						0828	103			83.87		1.8	1.7	3500	2069	
32						0829	103			83.87		1.4	1.4	3500	2586	
						0829	103	1420	1691	83.87		0.3	0.3	3500	12068	50 ft SW of Buoy Line
33						0829	103	1420	1691	83.87		0.3	0.3	3500	12068	
34						0836	105	1349	1721	84.16	35.44	0.2	0.2	4000	25580	200 ft
35						0838	105	1369	1694	84.01	35.44	0.3	0.3	4000	13757	
						0840	105	1378	1699	84.01	35.44	0.3	0.3	4000	15958	50 ft
36						0840	105			84.01	35.44	10.3	10.3	4000	387	
						0840	105	1384	1700	84.01	35.44	11.2	11.2	4000	356	
37						0841	105			84.01	35.44	4.8	4.8	4000	831	
						0841	105	1391	1699	84.02	35.40	5.8	5.8	4000	686	On Buoy Line
						0842	105			84.02	35.40	4.8	4.8	4000	829	
38						0842	105	1401	1699	84.02	35.43	6.0	6.0	4000	663	
39						0843	90	1415	1707	84.23	35.40	0.2	0.2	4000	18839	Above Plume
40						0845	90	1445	1715	84.23	35.40	0.1	0.1	4000	28983	100 ft SW of Buoy Line
41						0846	74	1463	1731	84.27	35.47	0.1	0.1	4500	32269	
						0847	75			84.28	35.48	0.1	0.2	4500	29886	
42						0849	58	1487	1724	84.32	35.49	0.1	0.2	4500	29577	300 ft SW
43						0850	40	1509	1725	84.43	35.46	0.1	0.2	4500	28743	300 ft SW
44						0853	25	1547	1734	84.60	35.45	0.1	0.2	4500	27500	
45						0855	6	1555	1744	84.60	35.49	0.1	0.2	4500	29616	

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Pt No.	Station	Sampling Location	Tide Stage	Mid-depth Current Speed and Direction	Bottom Current Speed and Direction	Time	Sampling Depth (feet)	Navigation Distances (m) Code 1	Code 4	Temp. (deg.F)	Salinity (ppt)	Measured Dye Concen. (ppb)	Temperature Corrected Reading (ppb)	Initial Dye Concen. (ppb)	Minimum Dilution Ratio (Initial/Field Measurement)	Comments
46	T-1	Near South Mixing	Ebbing	18.3 cm/sec	2.4 cm/sec	0908	115	1761	1766	84.16		0.1	0.1	5000	34259	
47		Zone Boundary		141 deg.	318 deg.	0910	111	1759	1792	84.16		0.1	0.1	5000	34259	
48		(S. of Toasa Rock)				0913	116	1759	1812	84.16		0.1	0.1	5000	34259	
49						0915	115	1774	1839	84.16		0.2	0.2	5000	31975	
50						0920	102	1774	1879	84.16		0.1	0.1	5000	34259	
51						0923	103	1796	1932	84.16		0.1	0.1	5000	34259	
52						0937	102	1744	1981	84.16		0.1	0.1	5500	37685	
53						0939	60	1764	1981	84.16		0.1	0.1	5500	37685	
54	P-3	At Drogue No. 1 –	Ebbing	17.7 cm/sec	3.1 cm/sec	0945	75	1563	1735	84.29	35.48	0.2	0.2	5500	34004	AT Drogue
55		Near Toasa Rock		158 deg.	328 deg.	0947	97	1589	1747	84.16	35.50	0.1	0.1	5500	37685	
56		Buoy				0949	115	1625	1762	84.05	35.53	0.1	0.1	5500	38778	AT TR Buoy
57						0950	145	1631	1762	84.03	35.54	0.1	0.1	6000	42524	
58	P-4	Diffuser Site	Ebbing	18.0 cm/sec	3.0 cm/sec	0959	146	1373	1699	84.03	35.54	12.6	12.7	6000	472	
		(Drifting N to S		145 deg.	318 deg.	0959	144			84.03	35.54	48.5	48.9	6000	123	
59		to Toasa Rk Buoy)				0959	144	1379	1699	84.03	35.54	39.7	40.0	6000	150	Over Diffuser Ports
						1000	142			84.03		29.7	29.9	6000	200	Over Diffuser Ports
60						1000	137	1396	1696	84.03		16.4	16.5	6000	363	Over Diffuser Ports
61						1001	135	1405	1713	84.03		12.6	12.7	6000	472	At Buoy Line
						1002	143			84.03		12.3	12.4	6000	484	
						1003	146			84.03		12.7	12.8	6000	469	
62						1003	146	1421	1697	83.82	35.48	13.1	12.5	6000	480	75 ft SW of Buoys
						1004	145				35.48					
63						1007	123	1500	1724	83.95		0.7	0.7	6000	8684	Drifted Off Plume
64						1009	121	1522	1730	83.95		3.1	3.1	6000	1961	
65						1010	116	1543	1733	83.95		4.4	4.3	6000	1381	
66						1010	121	1551	1736	83.95		6.5	6.4	6000	935	
67						1011	121	1563	1736	83.95	35.47	7.3	7.2	6000	833	
68	T-2	Diffuser Site	Ebbing	18.1 cm/sec	1.6 cm/sec	1025	125	1374	1698	83.96	35.51	0.3	0.3	6500	21893	
69		to Near Toasa		164 deg.	284 deg.	1026	125	1397	1712	83.96	35.51	5.5	5.4	6500	1194	
70		Rock Buoy				1027	155	1418	1715	83.96		13.7	13.6	6500	479	
						1028	155			83.78	35.48	15.1	14.3	6500	456	50 ft Past Buoy Line
71						1029	155	1431	1743	83.78	35.48	15.4	14.5	6500	447	

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	T-2	Diffuser Site				1030	155	1438	1735	83.78	35.48	14.0	13.2	6500	492	
72						1030	155	1443	1728	83.78	35.48	16.4	15.5	6500	420	
						1031	155	1449	1733	83.78	35.47	17.1	16.1	6500	402	162 ft Deep
						1032	155	1460	1803	83.78	35.48	13.4	12.7	6500	514	
73						1033	155	1469	1738	83.78	35.48	14.2	13.4	6500	485	
						1034	155	1483	1739	83.78	35.48	13.1	12.4	6500	525	Drogue No. 3 Deployed
						1037	155	1511	1765	83.78	35.48	9.5	9.0	6500	724	
74						1038	155	1529	1754	83.78	35.48	10.0	9.4	6500	688	400-500 ft From Outfall
						1041	155	1548	1767	83.78	35.48	1.2	1.1	6500	5736	
						1043	155	1543	1803	83.78	35.48	8.2	7.7	6500	839	
75						1044	155	1557	1797	83.78	35.48	5.6	5.3	6000	1135	
						1045	155	1534	1789	83.78	35.48	8.8	8.3	6000	722	
76						1046	155	1551	1799	83.78	35.48	6.8	6.4	6000	934	
						1047	155	1563	1807	83.78	35.48	6.1	5.8	6000	1042	
						1048	123	1557	1805	83.78		5.4	5.1	6000	1177	
77	P-5	Near South	ow Tid	16.3 cm/sec	0.7 cm/sec	1145	124	1720	1880	84.10	35.52	0.1	0.1	5500	38277	
78		Mixing Zone		276 deg.	56 deg.	1146	159	1743	1911	84.05	35.54	0.8	0.8	5500	6786	Near MZB
79		Boundary				1150	157	1810	1940	84.05	35.54	0.1	0.1	4000	28202	
80						1155	160	1756	1879	84.10	35.51	0.4	0.4	4000	9743	
81						1159	161	1775	1921	84.10	35.51	0.1	0.1	4000	27838	
82	T-3	Diffuser Site	Flood	17.9 cm/sec	0.6 cm/sec	1210	156	1358	1694	84.05		1.2	1.2	3500	2879	North of Diffuser
83		to Near Toasa		290 deg.	18 deg.	1213	142	1390	1726	84.05		0.5	0.5	3500	6910	
		Rock Buoy				1214	148			84.05		10.9	11.0	3500	317	
84						1214	144	1394	1746	84.05		12.6	12.8	3500	274	East of Marker Buoy
						1215	160	1387	1738	84.05		12.0	12.2	3500	288	
85						1215	160	1402	1753	84.05		10.4	10.5	3500	332	75 ft East of Marker Buoy
						1217	131	1394	1735	84.05		13.8	14.0	3500	250	North of Marker Buoy
86						1217	136	1403	1758	84.05		11.2	11.3	3500	308	East of Marker Buoy
87						1218	134	1427	1775	84.05		13.8	14.0	3500	250	Marker Buoy Line
						1218	136	1427	1775	84.05		10.8	10.9	3500	320	
88						1220	142	1453	1798	84.05		15.2	15.4	3500	227	
89						1221	140	1465	1804	84.05		1.2	1.2	3500	2879	East on Marker Buoy Lin

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	T-3	Diffuser Site				1225	141	1445	1761	84.05		11.6	11.8	3500	298	
90						1226	157	1479	1796	84.05		11.2	11.3	3500	308	
						1226	157	1479	1796	84.05		7.6	7.7	3500	455	
91						1227	154	1496	1812	84.05		6.4	6.5	3500	540	SE of Marker Buoy
92						1232	127	1553	1811	84.05		0.1	0.1	3500	24677	
						1235	126	1574	1811	84.05		0.8	0.8	4000	4935	
						1242	126	1574		84.05		0.8	0.8	4000		Repositioned
93						1243	166	1546	1802	84.05		1.6	1.6	4000	2468	
						1244	165	1556	1794	84.05		3.4	3.4	4000	1161	
94						1245	144	1567	1801	84.05		0.1	0.1	4000	28202	
95	T-4	East and South of	Flood	20.5 cm/sec	3.1 cm/sec	1254	163	1795	1967	84.05		0.1	0.1	4500	31728	Near MZB
96		Toasa Rock Buoy		289 deg.	130 deg.	1256	162	1839	2020	84.05		0.1	0.1	4500	31728	
						1259	163			84.05		0.1	0.1	5000	35253	
97						1300	133	1849	2020	84.05		0.1	0.1	5000	35253	
						1300	146	1849	2020	84.05		0.1	0.1	5000	35253	
98						1301	157	1859	2023	84.05		0.1	0.1	5000	35253	
99						1310	156	1714	1951	84.19		0.1	0.1	5000	33993	
						1311	142			84.19		0.1	0.1	5000	33993	
100						1312	143	1729	1965	84.19		0.1	0.1	5000	33993	
101						1313	130	1745	1989	84.19		0.1	0.1	5000	33993	
102						1314	97	1765	2011	84.19	35.50	0.1	0.1	5000	33993	
103	P-6	Diffuser Site	Flood	19.8 cm/sec	2.3 cm/sec	1415	150	1329	1600	84.19		0.1	0.1	5000	33993	NW of Diffuser
104		(Drifting towards		271 deg.	75 deg.	1418	145	1385	1727	84.19		11.1	11.7	5000	429	
		Toasa Rock)				1419	118		1739	84.19		10.6	11.1	5000	449	
						1419	126			84.19		18.0	18.9	5000	264	
						1420	139			84.19		17.1	18.0	5000	278	
105						1420	144	1442	1739	84.19		14.1	14.8	5000	338	
						1425	150	1440	1744	84.19		12.4	13.0	5000	384	
						1425	137	1440	1744	84.19		9.7	10.2	5000	491	
106						1434	141	1461	1735	84.19		5.7	6.0	5000	835	100 ft west of Buoy
107						1435	137	1480	1751	84.19		1.5	1.6	5000	3173	
108						1438	167	1534	1787	84.19		0.9	0.9	5000	5288	
						1438	161	1545	1798	84.19		1.6	1.7	5000	2974	

Table A-1
Field Measurements Collected February 17, 1993
Joint Cannery Dilution Study

Pt No.	Station	Sampling Location	Tide Stage	Mid-depth Current Speed and Direction	Bottom Current Speed and Direction	Time	Sampling Depth (feet)	Navigation Distances (m) Code 1	Navigation Distances (m) Code 4	Temp. (deg.F)	Salinity (ppt)	Measured Dye Concen. (ppb)	Temperature Corrected Reading (ppb)	Initial Dye Concen. (ppb)	Minimum Dilution Ratio (Initial/Field Measurement)	Comments
	P-6	Diffuser Site				1439	150	1545	1798	84.19		1.6	1.7	5000		Repositioned to NW of Di
109						1445	147	1378	1679	84.19		0.2	0.2	5000	23795	
110						1445	149	1388	1685	84.19		4.2	4.4	5000	1133	
111						1446	150	1401	1697	84.19		8.1	8.5	5000	588	
112						1451	151	1415	1709	84.19		13.4	14.1	5500	391	20 ft West of Marker Line
						1452	125			84.19		0.2	0.2	5500	26175	
113						1453	128	1486	1729	84.19		0.5	0.5	5500	10470	
										84.19						
114	P-7	Moving Profile From Diffuser to Near Toasa Rock	Flood	17.9 cm/sec 277 deg.	2.3 cm/sec 128 deg.	1530	145	1402	1694	84.19		17.6	18.5	6500	352	
115						1530	144	1406	1695	84.19		18.4	19.3	6500	336	
						1530	142			84.19		18.6	19.5	6500	333	
116						1532	140	1421	1702	84.19		18.5	19.4	6500	334	
						1532	140	1421	1702	84.19		18.0	18.9	6500	344	Drifting West
117						1533	140	1431	1715	84.19		17.6	18.5	6500	352	100 ft West of Buoy
118						1536	145	1428	1730	84.19		9.1	9.6	6500	680	25-40 ft West of Line
						1536	144	1428	1730	84.19		18.9	19.9	6500	327	
						1537	144	1428	1730	84.19		17.5	18.4	6500	354	
119						1538	156	1471	1758	84.19		5.5	5.8	6500	1125	Lowered Hose
						1539	147			84.19		7.0	7.4	6500	884	
120						1541	145	1500	1772	84.19		3.0	3.2	6500	2062	
121						1545	162	1469	1730	84.19		0.8	0.8	6000	7139	
122						1546	153	1476	1749	84.19		6.0	6.3	6000	952	
123						1550	157	1491	1741	84.19		0.1	0.1	6000	40791	
124						1551	154	1509	1761	84.19		0.9	0.9	6000	6345	
125						1552	162	1517	1764	84.19		0.7	0.7	6000	8158	
126	P-8	Southeast of Diffuser (parallel with reef)	Flood	17.9 cm/sec 276 deg.	0.6 cm/sec 90 deg.	1558	100	1470	1751	84.19		0.2	0.2	5500	26175	
127						1559	166	1463	1755	84.19		3.8	4.0	6000	1503	
						1600	166	1463	1755	84.19		4.0	4.2	6000	1428	
						1600	165	1460	1758	84.19		6.0	6.3	6000	952	
128						1602	165	1473	1770	84.19		5.5	5.8	6000	1038	
						1602	163	1473	1770	84.19		5.1	5.4	6000	1120	
129						1605	140	1498	1795	84.19		0.1	0.1	6000	40791	

Table A-1
Field Measurements Collected February 17, 1993
Joint Cannery Dilution Study

Pt No.	Station	Sampling Location	Tide Stage	Mid-depth Current Speed and Direction	Bottom Current Speed and Direction	Time	Sampling Depth (feet)	Navigation Distances (m) Code 1	Navigation Distances (m) Code 4	Temp. (deg.F)	Salinity (ppt)	Measured Dye Concen. (ppb)	Temperature Corrected Reading (ppb)	Initial Dye Concen. (ppb)	Minimum Dilution Ratio (Initial/Field Measurement)	Comments
130	P-8					1606	155	1530	1814	84.19		0.8	0.8	6000	7139	
131						1607	140	1548	1826	84.19		0.4	0.4	6000	14277	
132						1612	160	1436	1755	84.19		6.4	6.7	6000	892	
						1614	155	1436	1755	84.19		0.2	0.2	6000	28554	
133						1615	150	1473	1789	84.19		1.3	1.4	6000	4393	
						1615	151	1473	1789	84.19		3.6	3.8	5500	1454	
						1617	154	1504	1828	84.19		0.2	0.2	5500	26175	
134						1618	152	1508	1846	84.19		0.2	0.2	5500	26175	
135						1624	151	1506	1820	84.19		0.5	0.5	5500	10470	
136						1625	133	1512	1839	84.19		0.1	0.1	5500	40268	
137	T-5	Diffuser Transects	igh Tid	18.4 cm/sec	2.8 cm/sec	1640	150	1346	1640	84.19		0.3	0.3	5000	15863	75 ft N of Current Meters
138		(North-NE side		271 deg.	90 deg.	1641	160	1354	1678	84.19		0.4	0.4	5000	11898	
		of Diffuser				1642	151	1354	1678	84.19		0.4	0.4	5000	11898	50 ft N of Current Meters
								1365	1690	84.19		18.7	19.6	5000	254	Near Bouys
139						1643	149	1365	1690	84.19		17.8	18.7	5000	267	
						1644	140	1367	1711	84.19		10.4	10.9	5000	458	Mid-Marker Line
						1645	150	1367	1730	84.19		2.8	2.9	5000	1700	
140						1646	155	1372	1736	84.19		6.2	6.5	5000	768	
						1647	160	1372	1736	84.19		9.8	10.3	5000	486	
141						1648	150	1387	1737	84.19		10.5	11.0	5000	453	Near Outfall Marker
						1648	143	1387	1737	84.19		11.8	12.4	5000	403	
142						1648	142	1393	1746	84.19		0.3	0.3	5000	15863	
143						1652	144	1354	1686	84.19		0.2	0.2	5000	23795	N. of Line
						1652	145	1356	1696	84.19		9.3	9.8	5000	512	
						1653	145	1356	1696	84.19		7.2	7.6	5000	661	
144						1654	146	1364	1706	84.19		6.0	6.3	5000	793	
						1654	145	1378	1724	84.19		5.5	5.8	5000	865	
						1655	121	1378	1724	84.19		0.3	0.3	5000	17626	
145						1656	117	1387	1736	84.19		0.1	0.1	5000	36608	
						1659	86			84.19		0.2	0.2	5000	31727	
146						1700	5	1424	1754	84.19		0.2	0.2	5000	26439	

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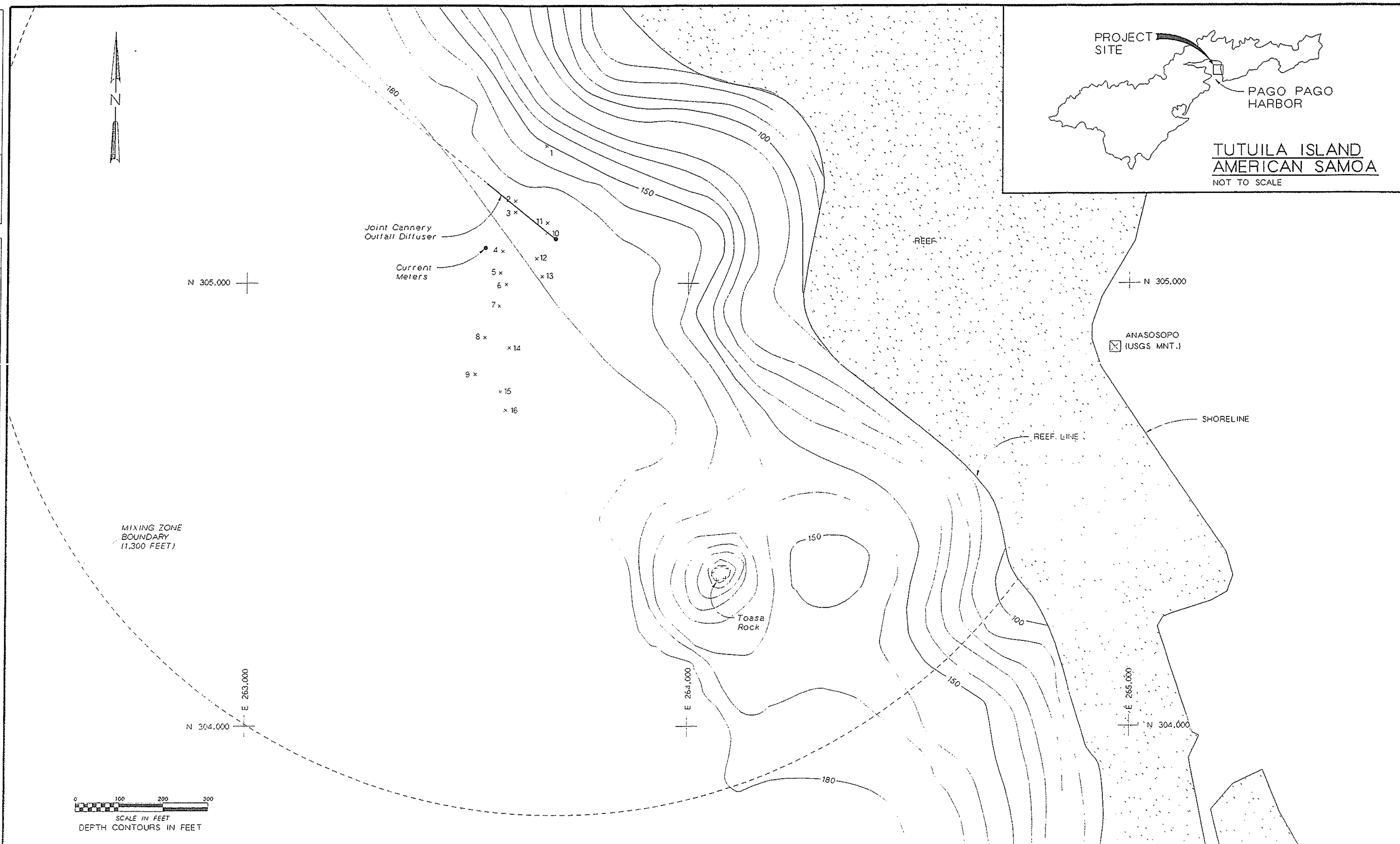
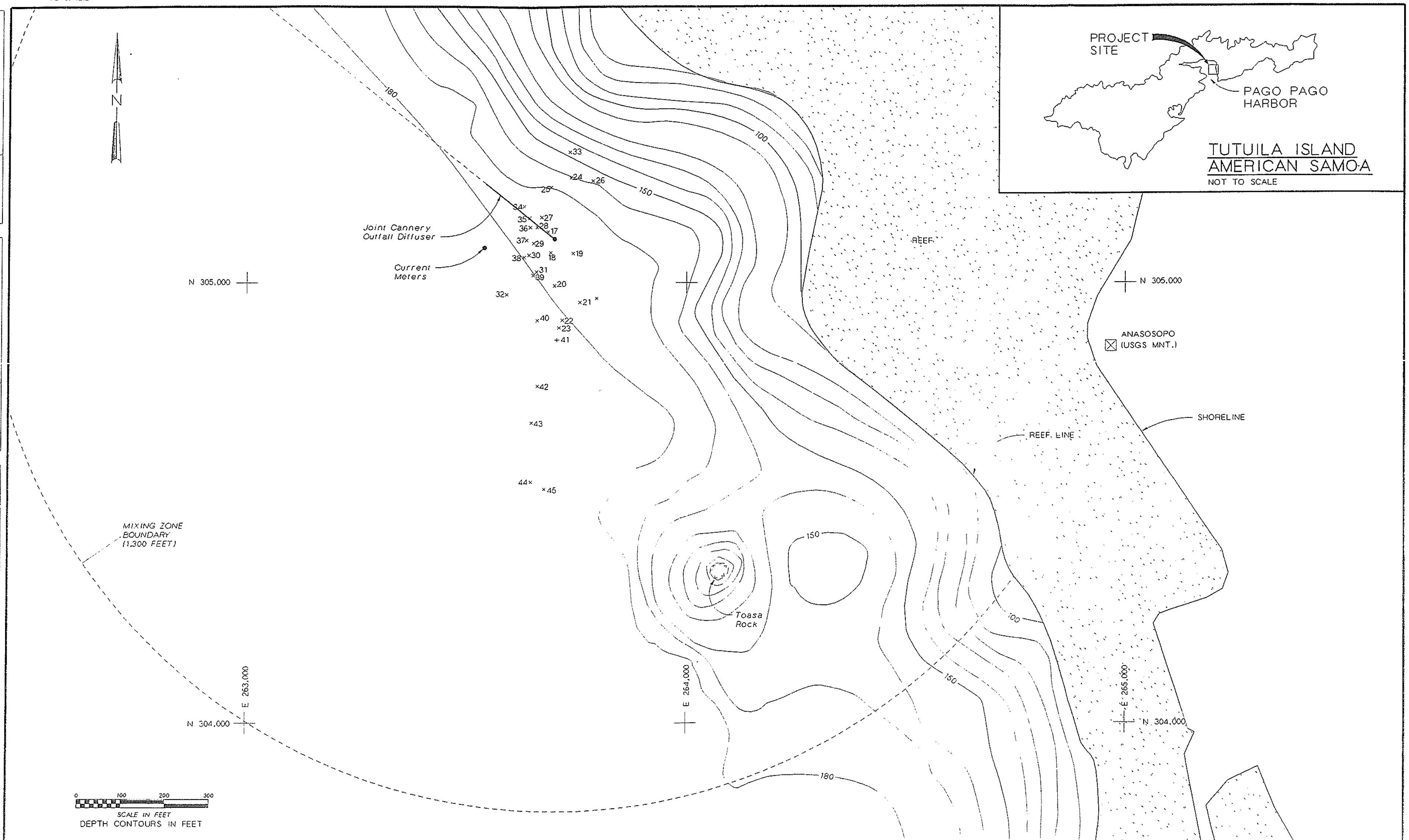


CH2M HILL

VCS SAMOA PACKING COMPANY INC. AND STARKIST SAMOA INC.

JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-1
PROFILE P-1 SAMPLING SITES.
0723-0755

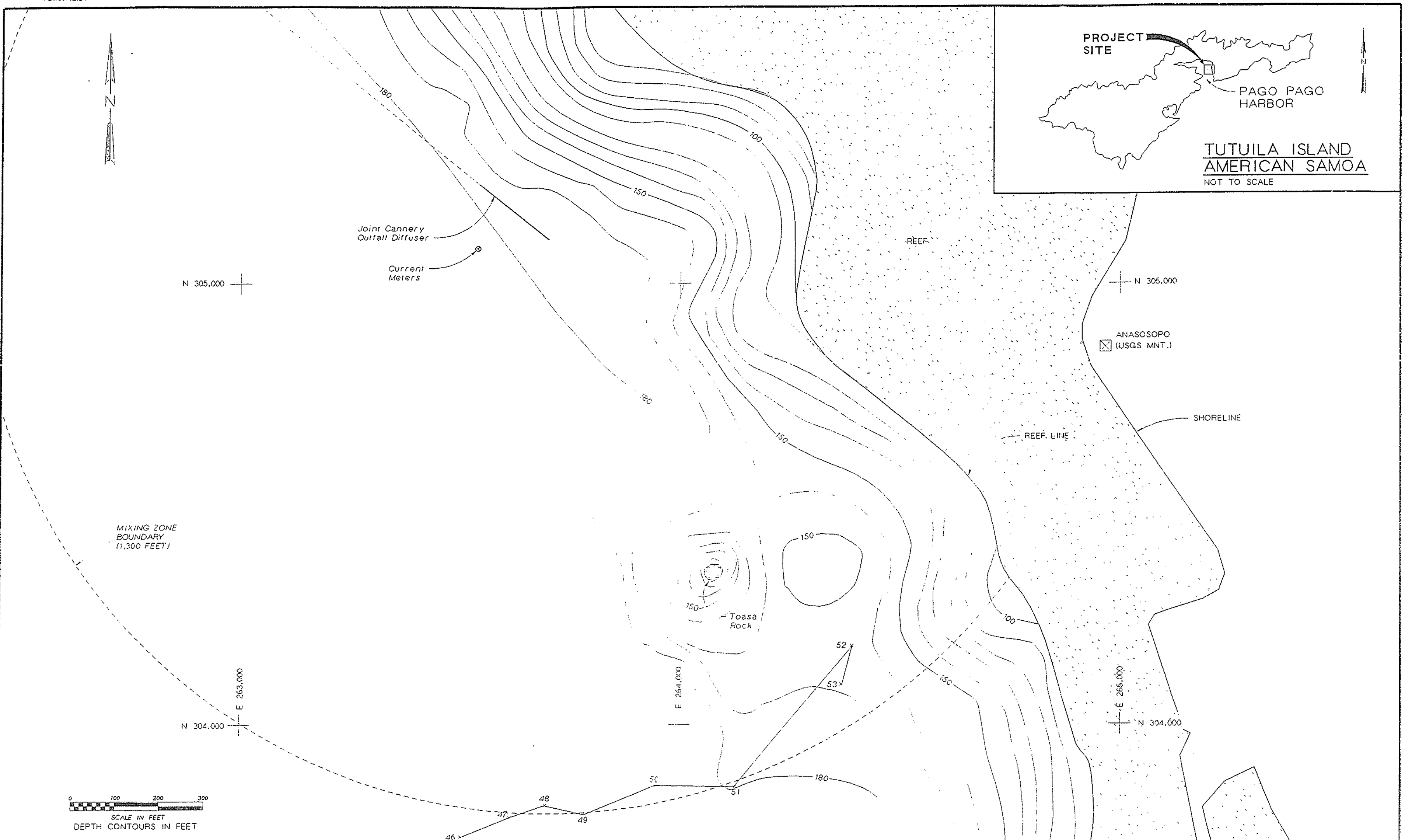


CH2M HILL

VCS SAMOA PACKING COMPANY INC. AND STARKIST SAMOA INC.

JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-2
PROFILE P-2 SAMPLING SITES, 0804-0855



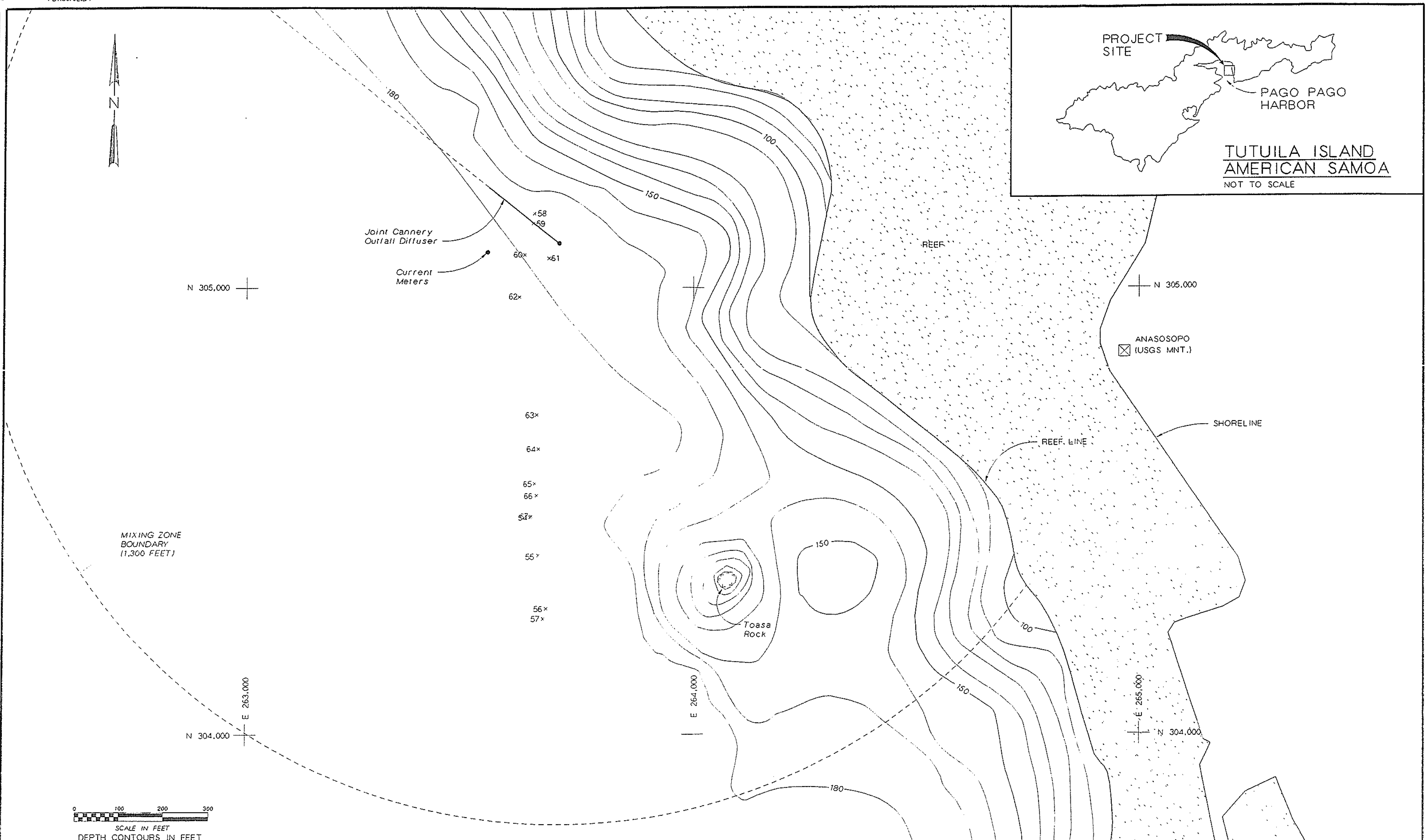
CH2M HILL

VCS SAMOA PACKING COMPANY INC. AND STARKIST SAMOA INC.

JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-3
TRANSECT T-1 SAMPLING SITES.
0908-0939

CONTROL DATE: 07:10:30 20-May-1993
02A4 DLV PDX30702.DY



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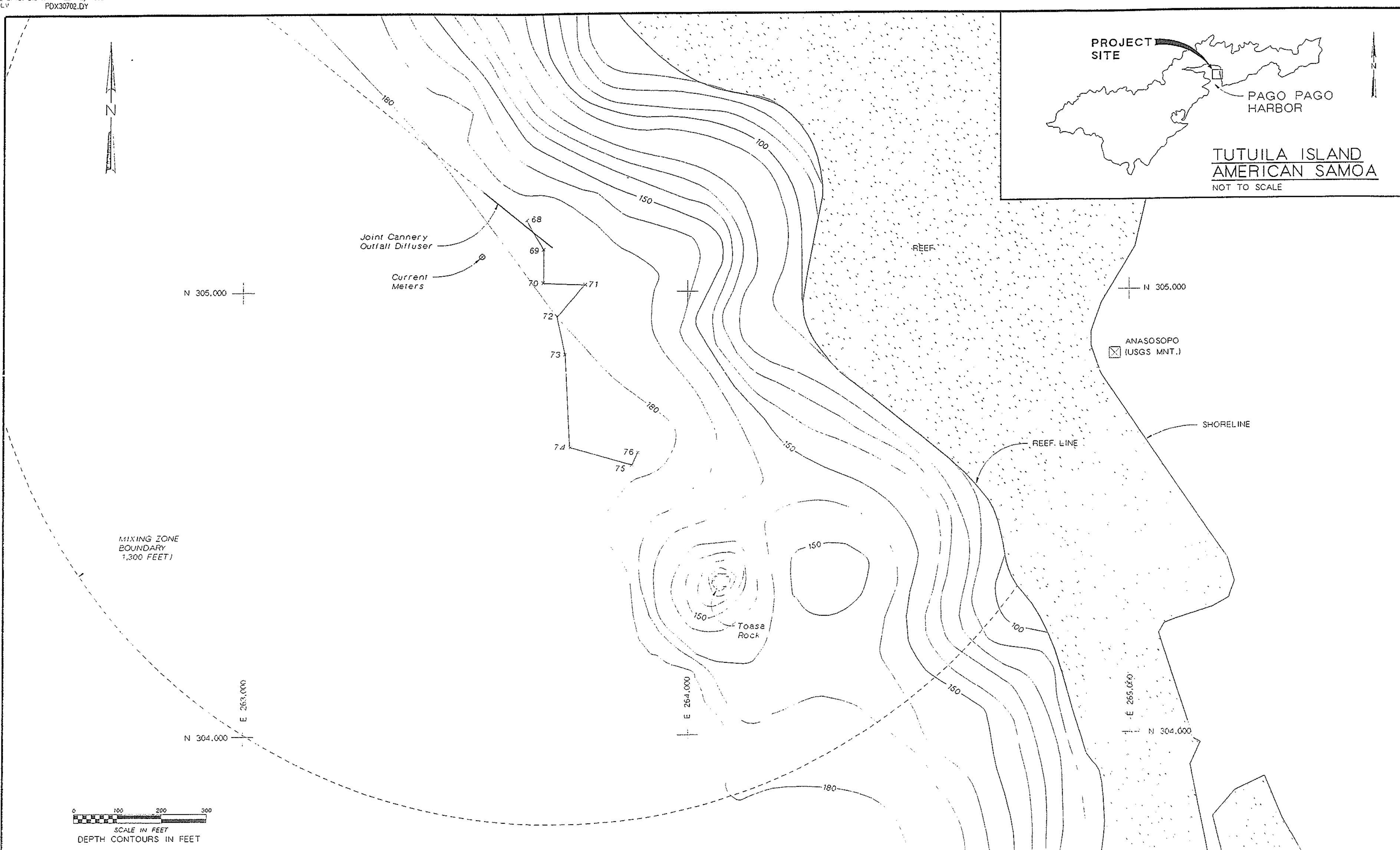
JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-4
PROFILES P-3 AND P-4 SAMPLING SITES,
0945-1012

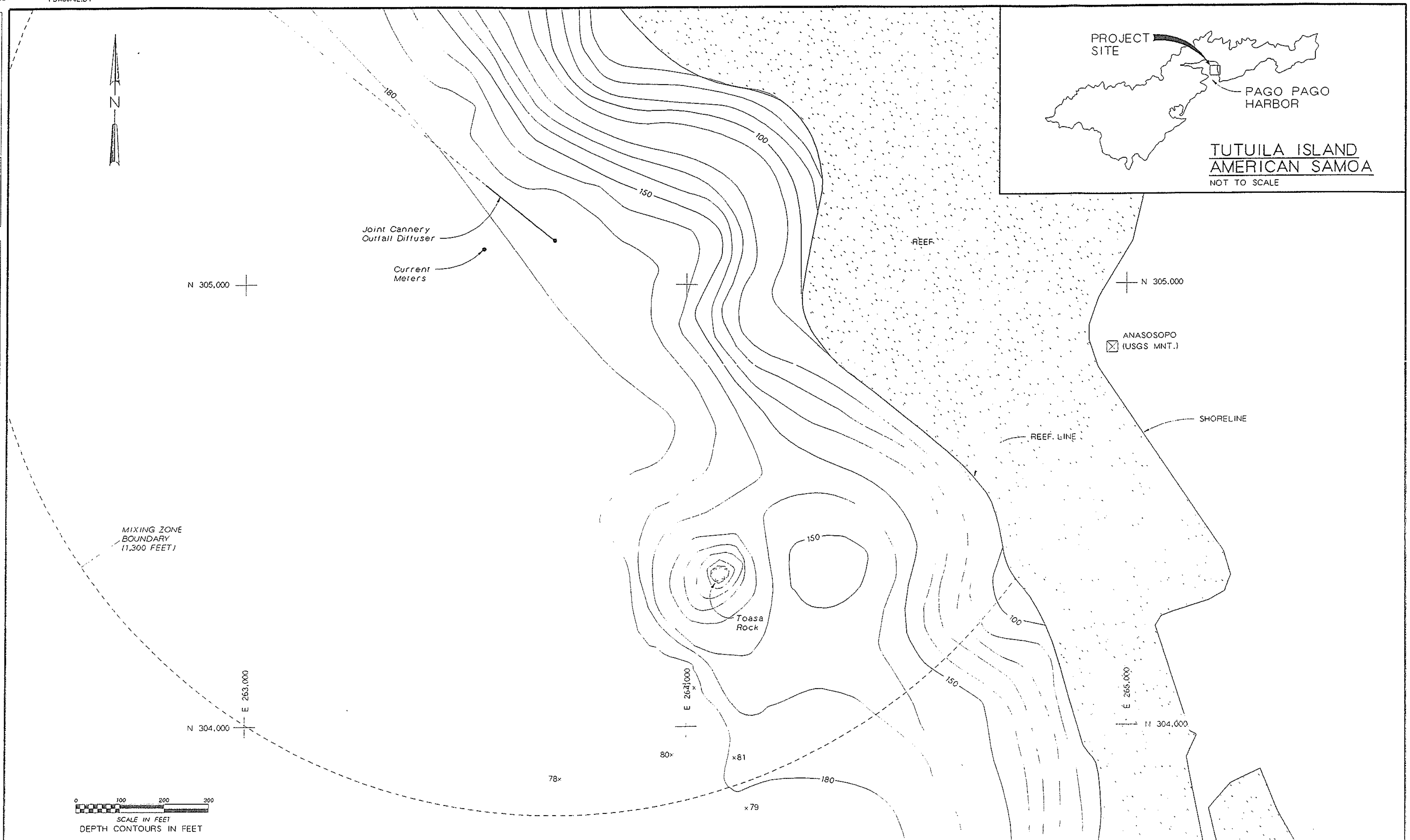


JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

VCS SAMOA PACKING COMPANY INC. AND STARKIST SAMOA INC.

Figure A-5
TRANSECT T-2 SAMPLING SITES, 1025-1048

CONTROL DATE: 09:21:41 20-May-1993
2A6.DLV PDX30702.DY

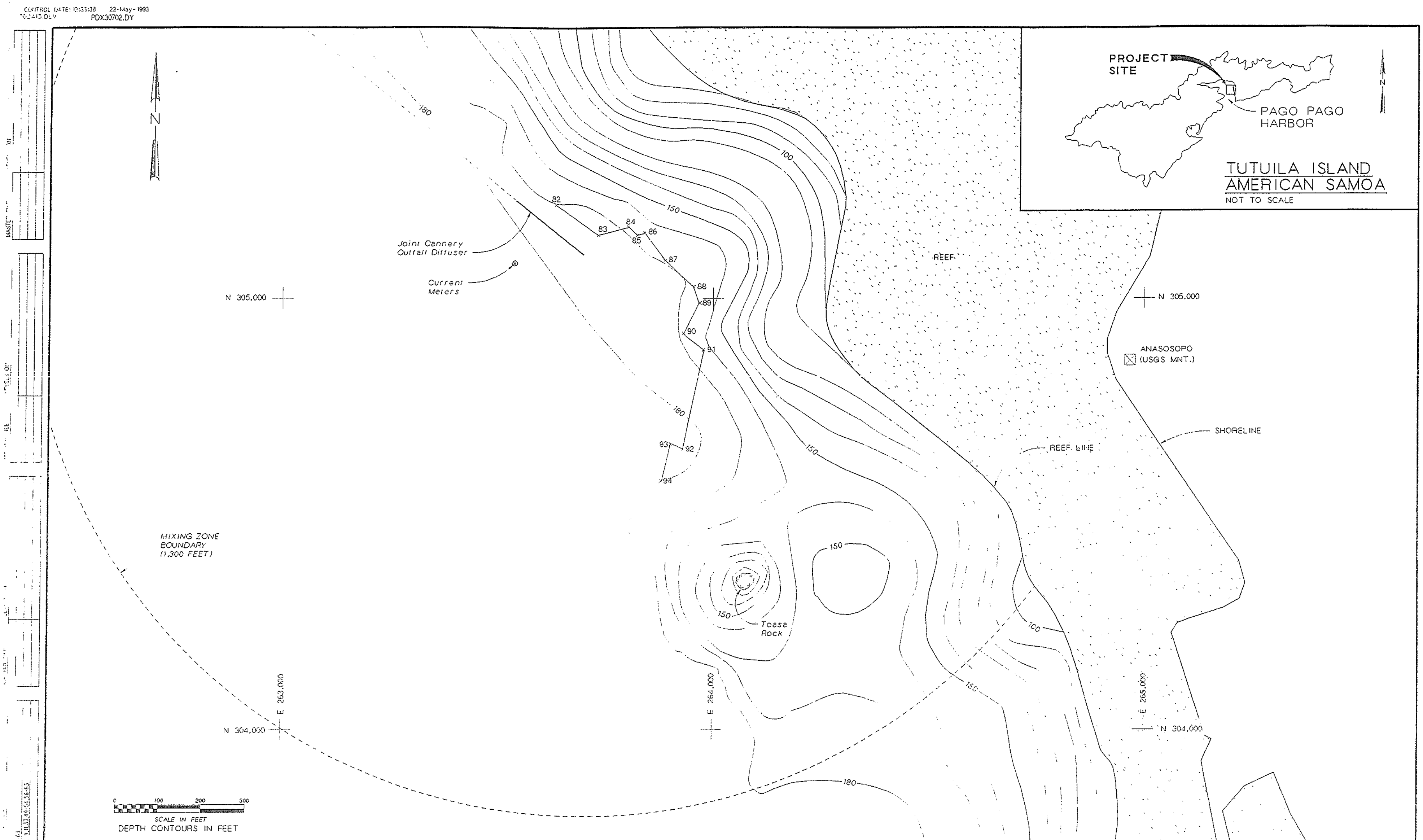


CH2M HILL

VCS SAMOA PACKING COMPANY INC AND STARKIST SAMOA INC.

JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-6
PROFILE P-5 SAMPLING SITES, 1145-1155



CH2M HILL

VCS SAMOA PACKING COMPANY INC. AND STARKIST SAMOA INC.

JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-7
TRANSECT T-3 SAMPLING SITES, 1210-1245

CONTROL DATE: 12:41:30 22-May-1993
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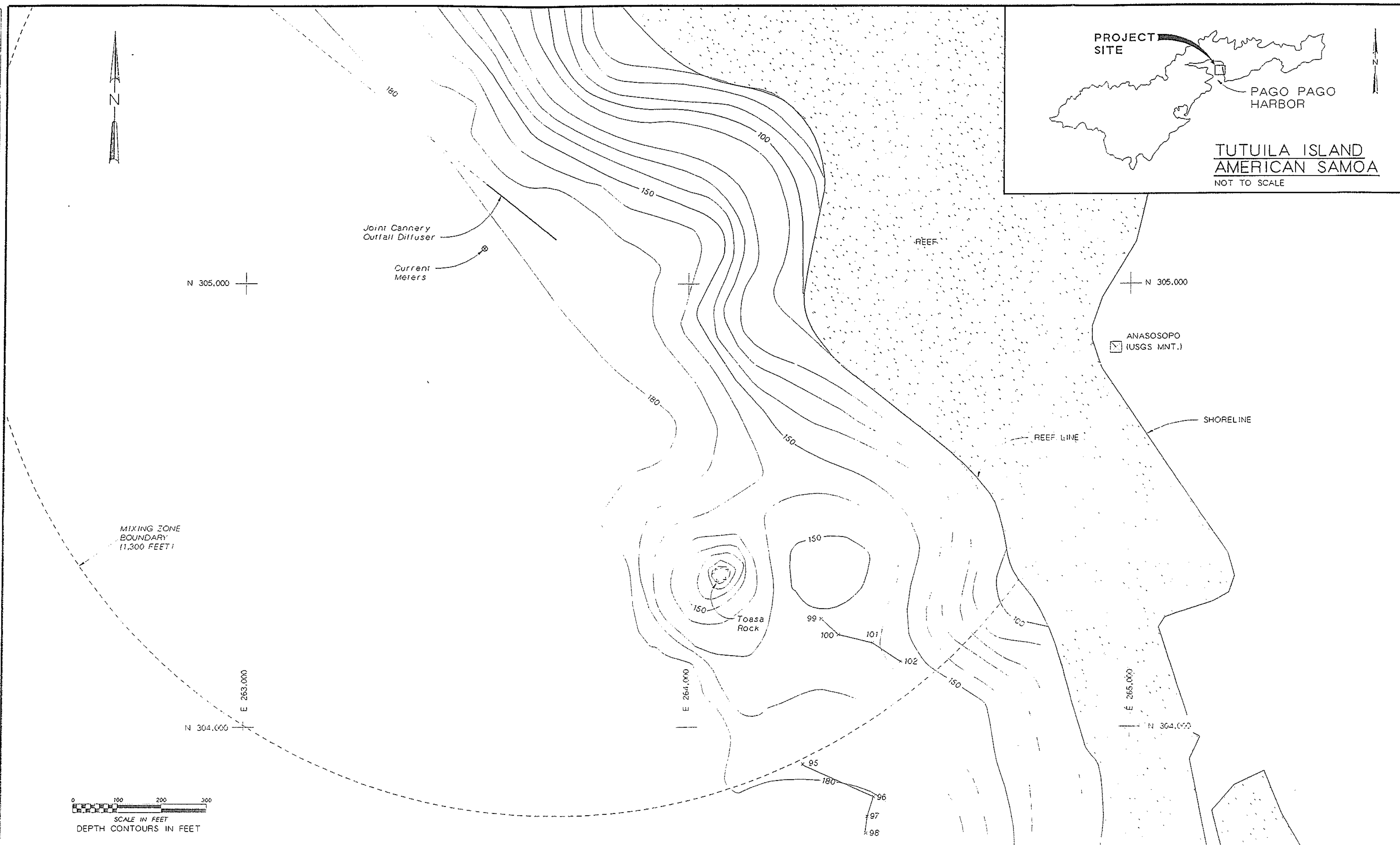

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JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-8
TRANSECT T-4 SAMPLING SITES,
1210-1245

CAD CONTROL DATE: 07:27:17 20-May-1993
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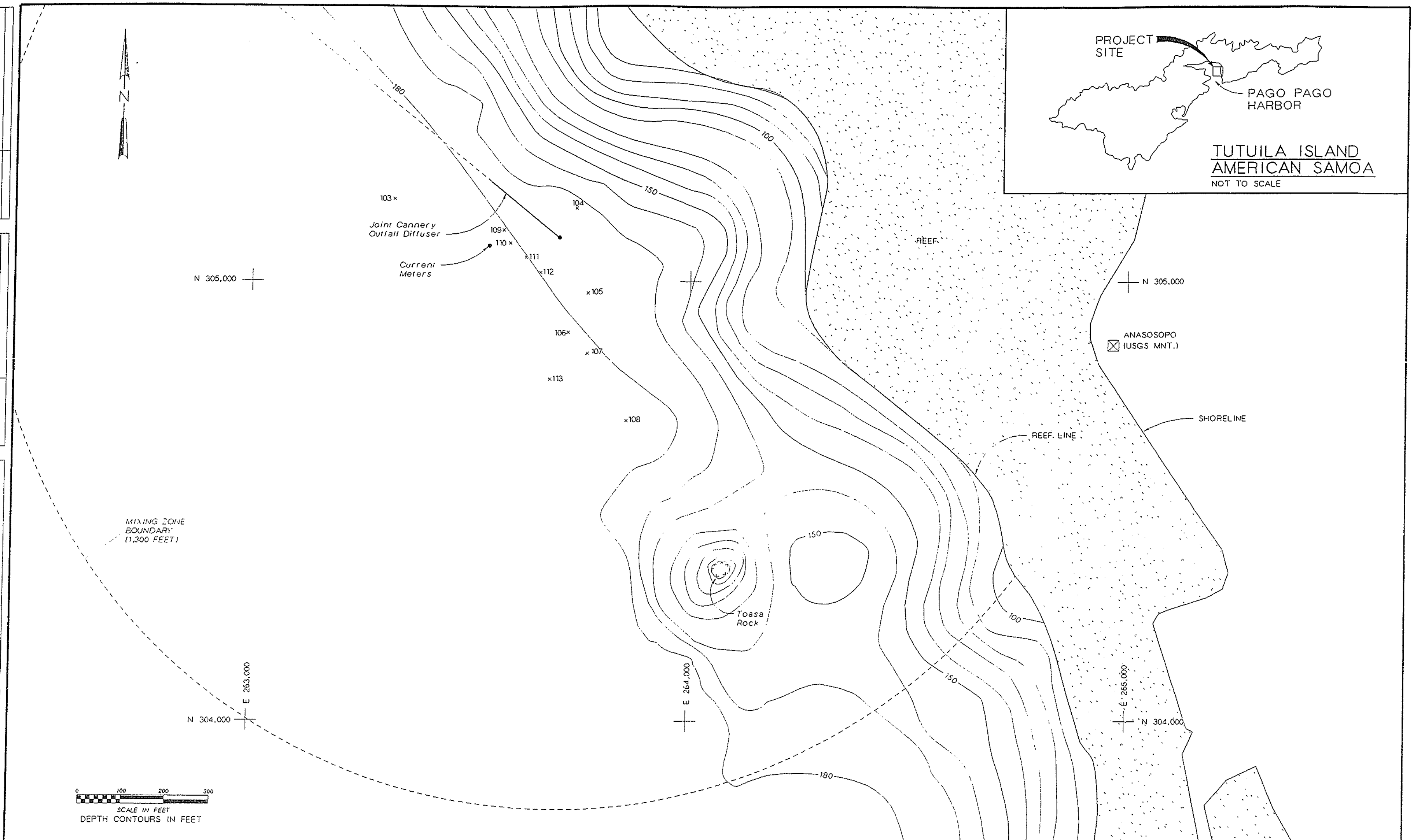
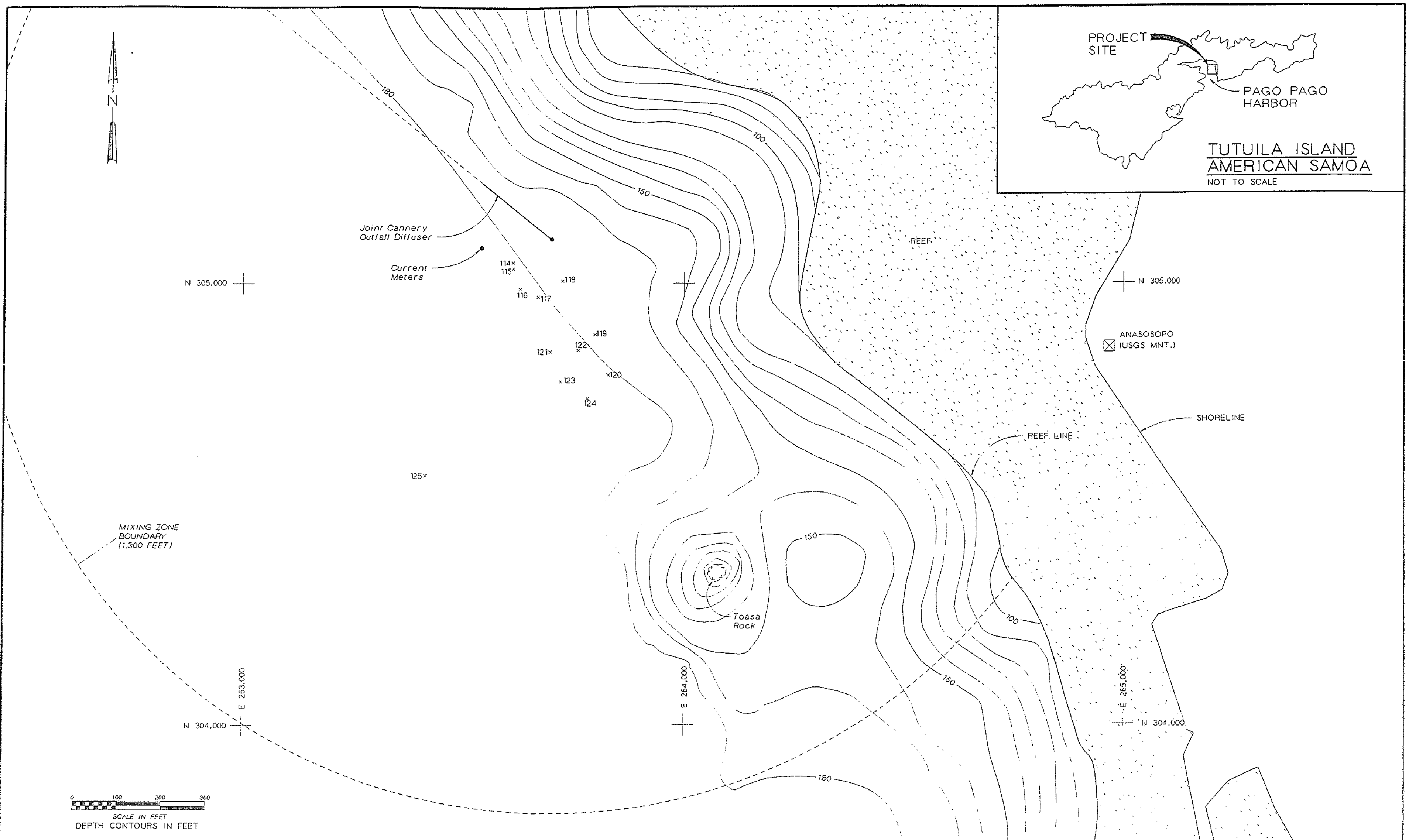


CH2M HILL

VCS SAMOA PACKING COMPANY INC. AND STARKIST SAMOA INC.

JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-9
PROFILE P-6 SAMPLING SITES, 1445-1453



VCS SAMOA PACKING COMPANY INC AND STARKIST SAMOA INC.

JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-10
PROFILE P-7 SAMPLING SITES, 1530-1552

CONTROL DATE: 07:35:24 20-May-1993
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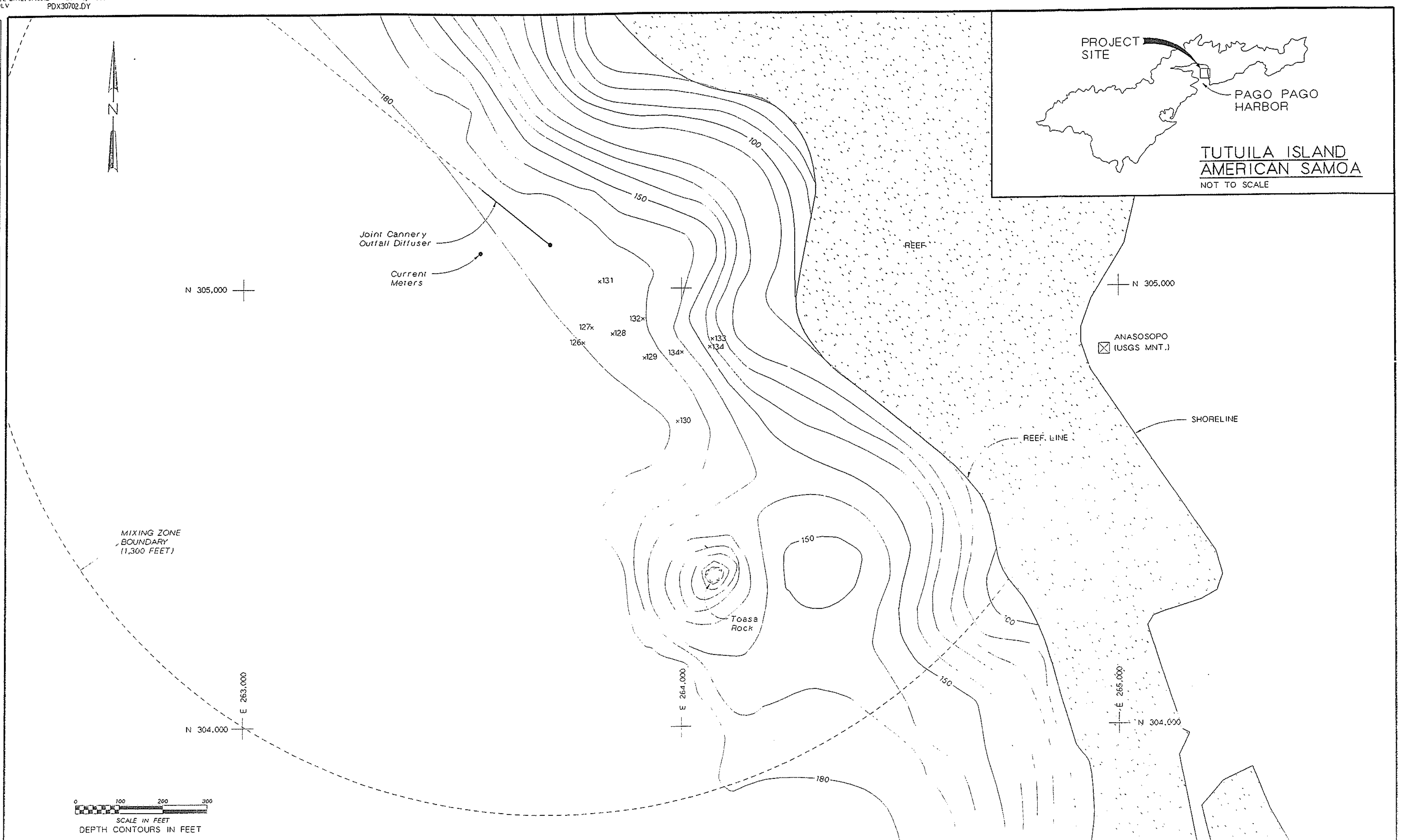

VCS SAMOA PACKING COMPANY, INC. AND STARKIST SAMOA INC.

JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-11
PROFILE P-8 SAMPLING SITES, 1558-1625

CONTROL DATE: 12:47:55 22-May-1993
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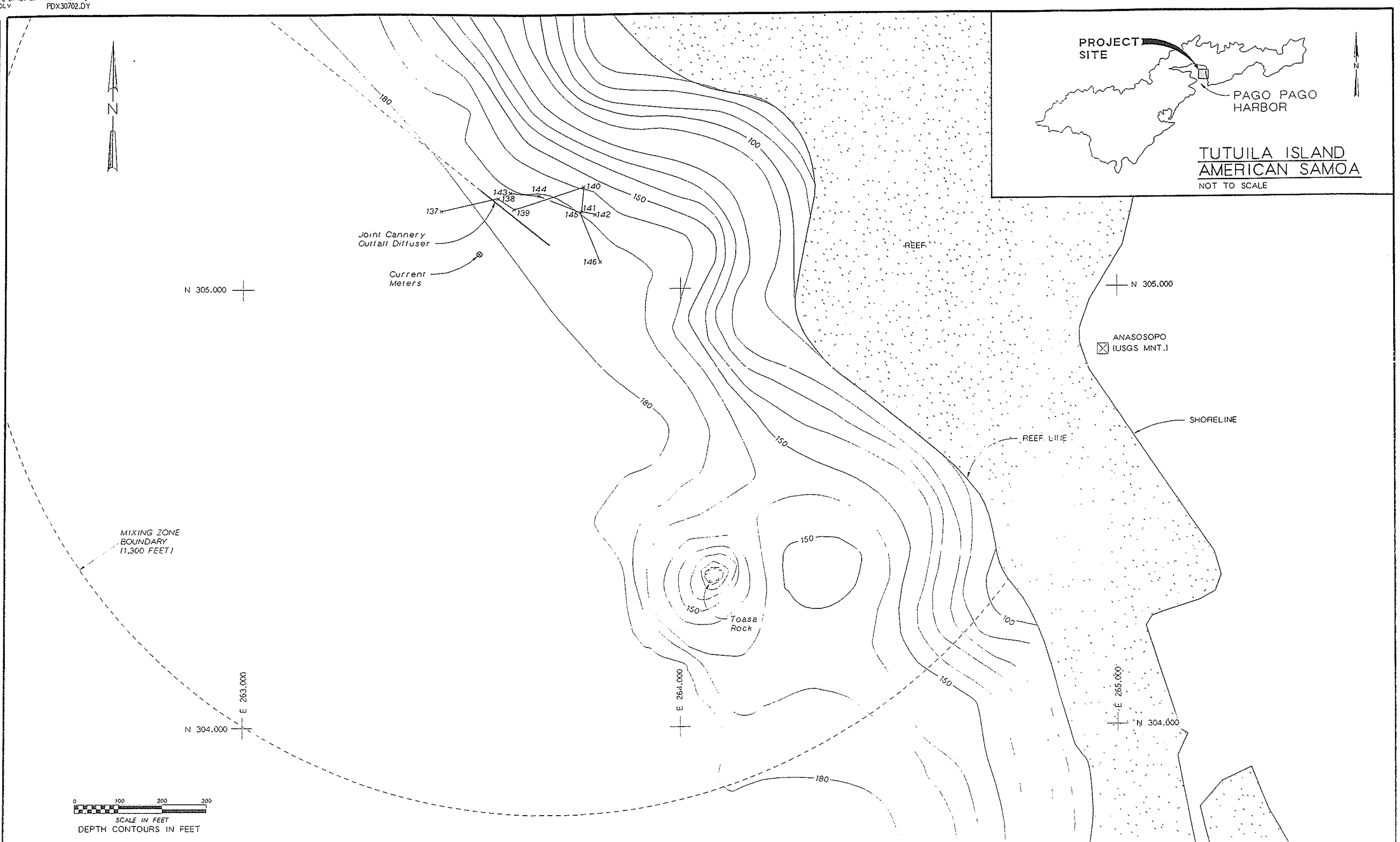

CH2M HILL

VCS SAMOA PACKING COMPANY, INC AND STARKIST SAMOA INC

JOINT CANNERY OUTFALL DILUTION STUDY - FEBRUARY 1993

Figure A-12
TRANSECT T-5 SAMPLING SITES.
1640-1700

APPENDIX B

CTD DATA

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone
(Profile 00 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
0.9	27.609	2.572	14.833	7.424
1.0	27.418	4.763	29.422	18.393
1.1	22.397	5.348	37.447	25.967
1.5	28.627	5.774	35.593	22.636
1.9	28.680	5.816	35.847	22.810
2.1	28.575	5.814	35.909	22.891
2.3	28.668	5.795	35.706	22.708
2.6	28.655	5.794	35.712	22.716
2.8	28.628	5.790	35.701	22.717
3.2	28.662	5.813	35.836	22.807
3.6	28.672	5.803	35.760	22.746
4.0	28.604	5.823	35.949	22.911
4.2	28.665	5.810	35.816	22.791
4.5	28.616	5.807	35.831	22.819
4.7	28.644	5.816	35.868	22.837
5.1	28.607	5.823	35.947	22.909
5.4	28.549	5.843	36.129	23.065
5.8	28.651	5.813	35.845	22.818
6.0	28.578	5.828	36.006	22.963
6.3	28.642	5.824	35.925	22.881
6.6	28.659	5.806	35.793	22.776
7.0	28.613	5.831	35.997	22.945
7.3	28.549	5.856	36.218	23.132
7.7	28.682	5.808	35.783	22.761
7.9	28.530	5.863	36.285	23.189
8.2	28.646	5.823	35.916	22.873
8.4	28.619	5.824	35.943	22.902
8.8	28.594	5.827	35.984	22.941
9.1	28.604	5.836	36.037	22.978
9.3	28.607	5.836	36.036	22.976
9.7	28.598	5.841	36.080	23.012
10.0	28.596	5.840	36.071	23.006
10.3	28.598	5.841	36.077	23.010
10.5	28.591	5.843	36.095	23.026
10.9	28.610	5.833	36.010	22.955
11.2	28.568	5.854	36.191	23.105
11.6	28.623	5.829	35.979	22.928
11.9	28.568	5.859	36.227	23.132
12.2	28.657	5.813	35.840	22.812
12.5	28.572	5.870	36.298	23.184
12.8	28.683	5.806	35.770	22.750
13.1	28.611	5.860	36.203	23.100

Joint Cannery Dilution Study
Non-Tradewind Season

CTD Profile in Mixing Zone
(Profile 00 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
13.4	28.680	5.807	35.776	22.756
13.7	28.607	5.864	36.231	23.123
14.0	28.668	5.815	35.847	22.813
14.3	28.598	5.866	36.254	23.142
14.6	28.704	5.802	35.723	22.708
15.0	28.555	5.883	36.400	23.267
15.5	28.809	5.793	35.584	22.569
15.8	28.568	5.887	36.422	23.279
16.1	28.809	5.786	35.536	22.533
16.4	28.546	5.878	36.375	23.251
16.6	28.830	5.791	35.556	22.540
16.6	28.689	5.806	35.762	22.743
16.5	28.791	5.789	35.570	22.564
16.4	28.804	5.785	35.531	22.531
16.4	28.773	5.793	35.612	22.602
16.5	28.810	5.789	35.556	22.547
16.8	28.735	5.792	35.634	22.631
17.1	28.733	5.804	35.716	22.694
17.4	28.782	5.807	35.702	22.667
17.8	28.697	5.744	35.328	22.413
18.2	29.115	5.869	35.878	22.687
18.5	28.769	5.803	35.680	22.654
18.8	28.642	5.858	36.161	23.058
19.1	28.720	5.806	35.743	22.718
19.4	28.655	5.873	36.257	23.126
19.6	28.826	5.781	35.485	22.489
19.9	28.641	5.880	36.318	23.176
20.1	28.848	5.779	35.458	22.461
20.5	28.680	5.827	35.919	22.863
20.6	28.808	5.791	35.566	22.556
21.0	28.774	5.800	35.660	22.638
21.2	28.834	5.795	35.579	22.556
21.4	28.826	5.797	35.596	22.572
21.7	28.824	5.797	35.602	22.578
22.0	28.825	5.799	35.612	22.584
22.2	28.811	5.799	35.622	22.597
22.5	28.792	5.802	35.655	22.628
22.7	28.804	5.804	35.659	22.627
22.8	28.830	5.805	35.649	22.610
22.9	28.841	5.794	35.563	22.543
23.2	28.806	5.797	35.610	22.590
23.5	28.771	5.804	35.684	22.657

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone
(Profile 00 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
24.0	28.825	5.803	35.637	22.604
24.3	28.755	5.729	35.176	22.280
24.7	29.109	5.833	35.633	22.505
25.1	29.022	5.805	35.504	22.438
25.4	28.961	5.805	35.550	22.492
25.8	28.823	5.791	35.555	22.542
26.1	28.747	5.825	35.852	22.791
26.5	28.742	5.849	36.020	22.919
26.8	28.795	5.799	35.634	22.611
27.3	28.707	5.822	35.859	22.809
27.7	28.995	5.779	35.347	22.329
28.2	28.720	5.812	35.777	22.743
28.5	28.791	5.806	35.685	22.651
28.9	28.805	5.809	35.695	22.654
29.3	28.813	5.805	35.658	22.623
29.7	28.801	5.807	35.687	22.649
30.2	28.833	5.799	35.603	22.575
30.5	28.807	5.804	35.659	22.626
30.9	28.829	5.799	35.604	22.577
31.4	28.825	5.800	35.615	22.587
32.0	28.848	5.797	35.580	22.553
32.3	28.838	5.799	35.596	22.568
32.5	28.840	5.799	35.597	22.569
32.9	28.825	5.801	35.622	22.592
33.2	28.838	5.800	35.605	22.575
33.7	28.843	5.797	35.580	22.555
34.0	28.827	5.797	35.593	22.570
34.4	28.826	5.798	35.603	22.578
34.8	28.813	5.801	35.633	22.604
35.2	28.818	5.803	35.641	22.608
35.5	28.823	5.801	35.624	22.595
35.9	28.819	5.803	35.637	22.606
36.3	28.802	5.804	35.662	22.629
36.6	28.811	5.804	35.651	22.619
37.0	28.798	5.805	35.669	22.636
37.4	28.881	5.805	35.604	22.560
37.8	28.963	5.804	35.539	22.484
38.2	29.046	5.804	35.475	22.408
38.5	28.758	5.807	35.712	22.682
38.9	28.764	5.808	35.712	22.680
39.3	28.761	5.807	35.712	22.681
39.8	28.745	5.811	35.748	22.714

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone
(Profile 00 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
40.2	28.747	5.808	35.726	22.696
40.6	28.759	5.807	35.714	22.683
40.9	28.748	5.810	35.740	22.706
41.2	28.725	5.815	35.793	22.754
41.6	28.742	5.811	35.750	22.716
42.0	28.733	5.816	35.791	22.750
42.4	28.765	5.812	35.742	22.702
42.7	28.739	5.817	35.793	22.749
43.1	28.752	5.815	35.773	22.730
43.4	28.727	5.820	35.822	22.775
43.8	28.748	5.816	35.778	22.734
44.2	28.713	5.820	35.834	22.789
44.5	28.727	5.815	35.789	22.750
44.8	28.719	5.812	35.775	22.742
45.1	28.724	5.811	35.767	22.735
45.5	28.696	5.815	35.811	22.777
45.9	28.709	5.814	35.796	22.761
46.2	28.730	5.810	35.755	22.724
46.6	28.716	5.813	35.783	22.749
46.9	28.723	5.813	35.778	22.743
47.2	28.724	5.812	35.769	22.736
47.4	28.700	5.815	35.807	22.773
47.6	28.724	5.810	35.756	22.727
47.8	28.730	5.801	35.691	22.676
48.1	28.703	5.807	35.754	22.732
48.3	28.708	5.805	35.734	22.716
48.5	28.702	5.805	35.738	22.720
48.6	28.695	5.805	35.741	22.725
48.7	28.712	5.801	35.701	22.689
48.8	28.693	5.806	35.750	22.732
48.9	28.711	5.804	35.723	22.706
49.0	28.697	5.807	35.758	22.737
49.0	28.687	5.807	35.764	22.745
49.2	28.673	5.810	35.794	22.772
49.2	28.686	5.809	35.781	22.758
49.3	28.672	5.816	35.835	22.803
49.5	28.692	5.808	35.767	22.745
49.6	28.672	5.816	35.834	22.803
49.7	28.704	5.803	35.720	22.706
49.7	28.677	5.806	35.767	22.750
49.9	28.682	5.803	35.740	22.728
50.0	28.690	5.801	35.719	22.710

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone
(Profile 00 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
50.0	28.675	5.801	35.731	22.724
50.1	28.688	5.800	35.713	22.706
50.2	28.659	5.805	35.767	22.757
50.2	28.700	5.799	35.699	22.691
50.4	28.682	5.802	35.730	22.721
50.5	28.690	5.803	35.730	22.718
50.8	28.676	5.806	35.762	22.747
51.0	28.682	5.805	35.751	22.737
51.3	28.682	5.808	35.776	22.755
51.5	28.638	5.815	35.858	22.832
51.9	28.674	5.806	35.764	22.749
52.2	28.629	5.815	35.865	22.840
52.5	28.640	5.810	35.816	22.800
52.9	28.603	5.817	35.894	22.870
53.2	28.626	5.809	35.822	22.809
53.4	28.587	5.817	35.907	22.886
53.6	28.615	5.806	35.811	22.804
53.7	28.597	5.811	35.856	22.844
53.6	28.632	5.797	35.736	22.742
53.7	28.597	5.799	35.777	22.784
53.7	28.568	5.802	35.817	22.824
53.8	28.571	5.797	35.777	22.793
53.8	28.542	5.797	35.805	22.824
53.9	28.528	5.797	35.810	22.832
54.1	28.493	5.795	35.828	22.857
54.1	28.457	5.800	35.890	22.916
54.2	28.452	5.796	35.860	22.895
54.3	28.441	5.795	35.864	22.902
54.3	28.436	5.796	35.872	22.909
54.4	28.413	5.797	35.901	22.939
54.5	28.430	5.793	35.858	22.901
54.5	28.425	5.792	35.854	22.899
54.6	28.416	5.798	35.903	22.939
54.6	28.405	5.800	35.928	22.962
54.7	28.418	5.797	35.897	22.934
54.6	28.418	5.799	35.909	22.943
54.6	28.424	5.797	35.890	22.927
54.7	28.421	5.796	35.882	22.922
54.7	28.384	5.800	35.939	22.977
54.7	28.408	5.792	35.866	22.914
54.7	28.388	5.799	35.928	22.967
54.8	28.414	5.796	35.891	22.930

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone
(Profile 00 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
54.8	28.399	5.798	35.914	22.953
54.8	28.404	5.795	35.894	22.936
54.8	28.382	5.792	35.891	22.941
54.9	28.413	5.788	35.838	22.891
55.0	28.366	5.802	35.968	23.004
55.0	28.385	5.795	35.909	22.954
55.2	28.364	5.794	35.918	22.968
55.3	28.369	5.789	35.879	22.937
55.5	28.323	5.801	35.997	23.041
55.8	28.365	5.792	35.898	22.952
56.1	28.324	5.803	36.010	23.050
56.3	28.349	5.797	35.948	22.995
56.3	28.319	5.808	36.050	23.082
56.3	28.348	5.793	35.920	22.974
56.3	28.329	5.793	35.935	22.992
56.3	28.344	5.790	35.903	22.963
56.3	28.330	5.791	35.918	22.979
56.3	28.332	5.789	35.901	22.965
56.3	28.345	5.785	35.867	22.936
56.4	28.342	5.784	35.863	22.934
56.5	28.332	5.782	35.855	22.931
56.7	28.334	5.780	35.840	22.919
56.9	28.303	5.778	35.850	22.937
57.1	28.290	5.779	35.865	22.952
57.3	28.267	5.780	35.890	22.979
57.4	28.279	5.782	35.896	22.979
57.3	28.277	5.776	35.855	22.949

Joint Cannery Dilution Study
Non-Tradewind Season

CTD Profile in Mixing Zone at Diffuser
(Profile 01 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
1.5	29.012	5.755	35.176	22.194
1.3	28.967	5.770	35.312	22.312
1.3	28.997	5.774	35.316	22.305
1.3	29.052	5.771	35.255	22.241
1.3	29.106	5.768	35.195	22.177
1.5	29.160	5.765	35.135	22.114
1.7	29.044	5.763	35.209	22.209
2.0	29.001	5.768	35.271	22.270
2.6	28.985	5.768	35.287	22.287
3.1	28.980	5.768	35.286	22.288
3.7	28.976	5.768	35.292	22.294
4.2	28.970	5.770	35.307	22.307
4.9	28.967	5.768	35.298	22.301
5.4	28.963	5.764	35.268	22.280
5.6	28.961	5.766	35.286	22.294
5.4	28.954	5.762	35.265	22.281
5.4	28.957	5.759	35.243	22.264
5.2	28.952	5.758	35.242	22.264
5.2	28.956	5.757	35.229	22.253
5.1	28.953	5.754	35.211	22.241
5.1	28.956	5.750	35.183	22.218
5.0	28.954	5.758	35.236	22.259
4.7	28.959	5.768	35.305	22.309
4.4	28.956	5.763	35.271	22.285
4.3	28.961	5.764	35.273	22.285
4.4	28.962	5.762	35.258	22.273
4.3	28.961	5.771	35.320	22.320
4.0	28.963	5.769	35.310	22.312
3.8	28.959	5.767	35.295	22.302
3.9	28.965	5.765	35.280	22.288
4.0	28.956	5.771	35.324	22.324
3.7	28.963	5.770	35.316	22.316
3.5	28.962	5.766	35.286	22.294
3.5	28.960	5.770	35.313	22.315
3.7	28.958	5.766	35.291	22.299
3.9	28.961	5.766	35.289	22.296
4.1	28.965	5.767	35.295	22.299
4.5	28.962	5.770	35.318	22.318
5.1	28.957	5.771	35.328	22.327
5.9	28.955	5.771	35.325	22.325
6.6	28.953	5.771	35.326	22.327
7.6	28.960	5.770	35.313	22.315
8.2	28.944	5.771	35.334	22.336

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone at Diffuser
(Profile 01 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
9.0	28.943	5.772	35.338	22.340
9.7	28.946	5.771	35.332	22.334
10.5	28.944	5.771	35.335	22.337
11.3	28.935	5.771	35.338	22.342
12.1	28.939	5.771	35.336	22.339
12.8	28.941	5.771	35.335	22.338
13.6	28.942	5.771	35.332	22.335
14.3	28.936	5.771	35.339	22.342
15.2	28.930	5.771	35.344	22.348
16.0	28.940	5.771	35.334	22.337
16.6	28.935	5.771	35.339	22.343
17.4	28.938	5.775	35.365	22.361
18.2	28.950	5.772	35.332	22.333
18.9	28.935	5.777	35.376	22.371
19.6	28.948	5.776	35.359	22.353
20.3	28.942	5.775	35.358	22.355
21.0	28.946	5.778	35.378	22.369
21.7	28.949	5.778	35.375	22.365
22.5	28.939	5.780	35.397	22.385
23.2	28.951	5.782	35.401	22.384
24.0	28.959	5.783	35.398	22.379
24.5	28.962	5.783	35.401	22.380
25.2	28.963	5.784	35.404	22.383
25.9	28.965	5.784	35.402	22.380
26.6	28.963	5.784	35.407	22.385
27.2	28.958	5.786	35.418	22.395
27.9	28.957	5.786	35.421	22.397
28.5	28.960	5.785	35.412	22.389
29.1	28.957	5.786	35.419	22.396
29.7	28.951	5.786	35.426	22.403
30.4	28.951	5.786	35.427	22.404
30.9	28.952	5.786	35.428	22.404
31.6	28.946	5.786	35.429	22.407
32.3	28.944	5.786	35.429	22.407
32.8	28.942	5.786	35.432	22.410
33.4	28.931	5.787	35.448	22.426
34.1	28.946	5.787	35.434	22.411
34.6	28.939	5.787	35.439	22.417
35.3	28.941	5.785	35.427	22.407
35.9	28.933	5.785	35.431	22.413
36.5	28.917	5.786	35.446	22.429
37.0	28.902	5.786	35.462	22.446
37.7	28.908	5.785	35.448	22.433

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone at Diffuser
(Profile 01 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
38.3	28.901	5.785	35.453	22.440
38.9	28.895	5.785	35.460	22.447
39.5	28.894	5.785	35.461	22.448
40.1	28.889	5.786	35.467	22.454
40.7	28.886	5.785	35.466	22.454
41.1	28.867	5.786	35.487	22.476
41.6	28.860	5.787	35.494	22.484
42.1	28.865	5.786	35.485	22.476
42.6	28.853	5.787	35.503	22.493
43.1	28.851	5.787	35.503	22.494
43.7	28.852	5.787	35.502	22.492
44.2	28.847	5.789	35.519	22.508
44.7	28.832	5.789	35.528	22.519
45.1	28.826	5.795	35.576	22.557
45.6	28.799	5.789	35.554	22.549
46.1	28.803	5.790	35.556	22.550
46.7	28.799	5.793	35.583	22.571
47.1	28.799	5.796	35.607	22.589
47.6	28.797	5.802	35.648	22.621
48.1	28.852	5.773	35.402	22.418
48.6	28.755	5.780	35.522	22.540
48.8	28.803	5.781	35.498	22.507
49.2	28.787	5.784	35.529	22.535
49.5	28.791	5.784	35.529	22.533
50.0	28.811	5.784	35.514	22.516
50.4	28.807	5.786	35.525	22.525
50.9	28.800	5.787	35.539	22.538
51.3	28.802	5.786	35.534	22.534
51.8	28.803	5.787	35.536	22.535
52.4	28.804	5.786	35.529	22.529
52.8	28.801	5.787	35.534	22.534
53.2	28.799	5.785	35.523	22.526
53.6	28.785	5.782	35.513	22.524
54.1	28.752	5.774	35.481	22.511
54.5	28.642	5.770	35.538	22.590
55.0	28.579	5.770	35.582	22.644
55.5	28.543	5.767	35.590	22.662
55.9	28.576	5.764	35.543	22.615
56.4	28.609	5.760	35.495	22.569
56.8	28.641	5.757	35.448	22.522
56.9	28.451	5.765	35.646	22.734
56.9	28.460	5.764	35.633	22.722
56.9	28.455	5.759	35.599	22.698

Joint Cannery Dilution Study
Non-Tradewind Season

CTD Profile in Mixing Zone North of Diffuser
(Profile 02 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (C)	Cond (S/m)	Salinity (PSU)	Sigma-t
1.5	29.012	5.755	35.176	22.194
1.3	28.967	5.770	35.312	22.312
1.3	28.997	5.774	35.316	22.305
1.3	29.052	5.771	35.255	22.241
1.3	29.106	5.768	35.195	22.177
1.5	29.160	5.765	35.135	22.114
1.7	29.044	5.763	35.209	22.209
2.0	29.001	5.768	35.271	22.270
2.6	28.985	5.768	35.287	22.287
3.1	28.980	5.768	35.286	22.288
3.7	28.976	5.768	35.292	22.294
4.2	28.970	5.770	35.307	22.307
4.9	28.967	5.768	35.298	22.301
5.4	28.963	5.764	35.268	22.280
5.6	28.961	5.766	35.286	22.294
5.4	28.954	5.762	35.265	22.281
5.4	28.957	5.759	35.243	22.264
5.2	28.952	5.758	35.242	22.264
5.2	28.956	5.757	35.229	22.253
5.1	28.953	5.754	35.211	22.241
5.1	28.956	5.750	35.183	22.218
5.0	28.954	5.758	35.236	22.259
4.7	28.959	5.768	35.305	22.309
4.4	28.956	5.763	35.271	22.285
4.3	28.961	5.764	35.273	22.285
4.4	28.962	5.762	35.258	22.273
4.3	28.961	5.771	35.320	22.320
4.0	28.963	5.769	35.310	22.312
3.8	28.959	5.767	35.295	22.302
3.9	28.965	5.765	35.280	22.288
4.0	28.956	5.771	35.324	22.324
3.7	28.963	5.770	35.316	22.316
3.5	28.962	5.766	35.286	22.294
3.5	28.960	5.770	35.313	22.315
3.7	28.958	5.766	35.291	22.299
3.9	28.961	5.766	35.289	22.296
4.1	28.965	5.767	35.295	22.299
4.5	28.962	5.770	35.318	22.318
5.1	28.957	5.771	35.328	22.327
5.9	28.955	5.771	35.325	22.325
6.6	28.953	5.771	35.326	22.327
7.6	28.960	5.770	35.313	22.315

Joint Cannery Dilution Study
Non-Tradewind Season

CTD Profile in Mixing Zone North of Diffuser
(Profile 02 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (C)	Cond (S/m)	Salinity (PSU)	Sigma-t
8.2	28.944	5.771	35.334	22.336
9.0	28.943	5.772	35.338	22.340
9.7	28.946	5.771	35.332	22.334
10.5	28.944	5.771	35.335	22.337
11.3	28.935	5.771	35.338	22.342
12.1	28.939	5.771	35.336	22.339
12.8	28.941	5.771	35.335	22.338
13.6	28.942	5.771	35.332	22.335
14.3	28.936	5.771	35.339	22.342
15.2	28.930	5.771	35.344	22.348
16.0	28.940	5.771	35.334	22.337
16.6	28.935	5.771	35.339	22.343
17.4	28.938	5.775	35.365	22.361
18.2	28.950	5.772	35.332	22.333
18.9	28.935	5.777	35.376	22.371
19.6	28.948	5.776	35.359	22.353
20.3	28.942	5.775	35.358	22.355
21.0	28.946	5.778	35.378	22.369
21.7	28.949	5.778	35.375	22.365
22.5	28.939	5.780	35.397	22.385
23.2	28.951	5.782	35.401	22.384
24.0	28.959	5.783	35.398	22.379
24.5	28.962	5.783	35.401	22.380
25.2	28.963	5.784	35.404	22.383
25.9	28.965	5.784	35.402	22.380
26.6	28.963	5.784	35.407	22.385
27.2	28.958	5.786	35.418	22.395
27.9	28.957	5.786	35.421	22.397
28.5	28.960	5.785	35.412	22.389
29.1	28.957	5.786	35.419	22.396
29.7	28.951	5.786	35.426	22.403
30.4	28.951	5.786	35.427	22.404
30.9	28.952	5.786	35.428	22.404
31.6	28.946	5.786	35.429	22.407
32.3	28.944	5.786	35.429	22.407
32.8	28.942	5.786	35.432	22.410
33.4	28.931	5.787	35.448	22.426
34.1	28.946	5.787	35.434	22.411
34.6	28.939	5.787	35.439	22.417
35.3	28.941	5.785	35.427	22.407
35.9	28.933	5.785	35.431	22.413
36.5	28.917	5.786	35.446	22.429

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone North of Diffuser
(Profile 02 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (C)	Cond (S/m)	Salinity (PSU)	Sigma-t
37.0	28.902	5.786	35.462	22.446
37.7	28.908	5.785	35.448	22.433
38.3	28.901	5.785	35.453	22.440
38.9	28.895	5.785	35.460	22.447
39.5	28.894	5.785	35.461	22.448
40.1	28.889	5.786	35.467	22.454
40.7	28.886	5.785	35.466	22.454
41.1	28.867	5.786	35.487	22.476
41.6	28.860	5.787	35.494	22.484
42.1	28.865	5.786	35.485	22.476
42.6	28.853	5.787	35.503	22.493
43.1	28.851	5.787	35.503	22.494
43.7	28.852	5.787	35.502	22.492
44.2	28.847	5.789	35.519	22.508
44.7	28.832	5.789	35.528	22.519
45.1	28.826	5.795	35.576	22.557
45.6	28.799	5.789	35.554	22.549
46.1	28.803	5.790	35.556	22.550
46.7	28.799	5.793	35.583	22.571
47.1	28.799	5.796	35.607	22.589
47.6	28.797	5.802	35.648	22.621
48.1	28.852	5.773	35.402	22.418
48.6	28.755	5.780	35.522	22.540
48.8	28.803	5.781	35.498	22.507
49.2	28.787	5.784	35.529	22.535
49.5	28.791	5.784	35.529	22.533
50.0	28.811	5.784	35.514	22.516
50.4	28.807	5.786	35.525	22.525
50.9	28.800	5.787	35.539	22.538
51.3	28.802	5.786	35.534	22.534
51.8	28.803	5.787	35.536	22.535
52.4	28.804	5.786	35.529	22.529
52.8	28.801	5.787	35.534	22.534
53.2	28.799	5.785	35.523	22.526
53.6	28.785	5.782	35.513	22.524
54.1	28.752	5.774	35.481	22.511
54.5	28.642	5.770	35.538	22.590
55.0	28.579	5.770	35.582	22.644
55.5	28.543	5.767	35.590	22.662
55.9	28.576	5.764	35.543	22.615
56.4	28.609	5.760	35.495	22.569
56.8	28.641	5.757	35.448	22.522

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone North of Diffuser
(Profile 02 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (C)	Cond (S/m)	Salinity (PSU)	Sigma-t
56.9	28.451	5.765	35.646	22.734
56.9	28.460	5.764	35.633	22.722
56.9	28.455	5.759	35.599	22.698
56.5	28.445	5.764	35.645	22.736
55.9	28.465	5.763	35.623	22.712
55.2	28.497	5.768	35.630	22.707
54.5	28.523	5.772	35.641	22.707
53.9	28.573	5.778	35.642	22.691
53.2	28.672	5.780	35.587	22.617

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profiles in Mixing Zone
(Profile 03 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (C)	Cond (S/m)	Salinity (PSU)	Sigma-t
1.3	28.912	5.726	35.046	22.131
1.3	28.946	5.719	34.976	22.067
1.7	28.955	5.724	35.006	22.086
2.0	28.960	5.723	34.993	22.075
2.0	28.964	5.722	34.980	22.064
2.2	28.969	5.720	34.968	22.053
2.3	28.892	5.711	34.961	22.073
2.5	28.884	5.706	34.932	22.054
2.6	28.891	5.709	34.949	22.064
2.8	28.884	5.714	34.987	22.095
3.0	28.887	5.722	35.038	22.133
3.3	28.883	5.727	35.079	22.165
3.6	28.885	5.719	35.022	22.121
3.8	28.882	5.714	34.990	22.098
4.0	28.890	5.708	34.942	22.060
4.1	28.895	5.715	34.984	22.090
4.3	28.894	5.723	35.043	22.134
4.5	28.901	5.725	35.048	22.135
4.7	28.901	5.714	34.973	22.080
4.9	28.906	5.731	35.089	22.164
5.0	28.916	5.721	35.010	22.102
5.1	28.906	5.724	35.041	22.128
5.1	28.912	5.728	35.064	22.144
5.2	28.915	5.732	35.090	22.162
5.4	28.916	5.723	35.024	22.113
5.7	28.920	5.725	35.032	22.117
5.9	28.925	5.721	35.004	22.095
6.1	28.919	5.730	35.070	22.146
6.3	28.933	5.731	35.064	22.137
6.5	28.927	5.726	35.038	22.120
6.7	28.932	5.721	34.996	22.086
6.9	28.938	5.718	34.976	22.069
7.1	28.932	5.720	34.989	22.081
7.2	28.934	5.721	34.994	22.083
7.3	28.929	5.719	34.987	22.080
7.5	28.937	5.719	34.978	22.070
7.7	28.932	5.730	35.061	22.135
7.9	28.932	5.740	35.129	22.186
8.1	28.930	5.753	35.217	22.253
8.3	28.931	5.758	35.251	22.278
8.8	28.934	5.760	35.264	22.286
9.2	28.936	5.760	35.264	22.286

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profiles in Mixing Zone
(Profile 03 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (C)	Cond (S/m)	Salinity (PSU)	Sigma-t
9.7	28.937	5.761	35.268	22.289
10.2	28.933	5.762	35.281	22.300
10.7	28.940	5.762	35.274	22.292
11.3	28.938	5.764	35.286	22.302
11.8	28.940	5.764	35.285	22.301
12.3	28.951	5.764	35.281	22.294
12.7	28.947	5.765	35.285	22.299
13.2	28.954	5.766	35.293	22.302
13.7	28.955	5.766	35.286	22.297
14.1	28.946	5.766	35.293	22.304
14.6	28.945	5.765	35.292	22.304
15.0	28.941	5.765	35.291	22.305
15.3	28.937	5.765	35.292	22.307
15.8	28.937	5.764	35.288	22.304
16.0	28.926	5.764	35.296	22.313
16.2	28.926	5.763	35.286	22.306
16.5	28.920	5.763	35.294	22.314
16.8	28.919	5.763	35.295	22.315
17.2	28.922	5.763	35.292	22.312
17.6	28.919	5.763	35.294	22.314
18.0	28.922	5.763	35.293	22.312
18.3	28.916	5.763	35.295	22.316
18.5	28.910	5.762	35.294	22.318
18.7	28.906	5.763	35.304	22.326
19.0	28.907	5.764	35.307	22.328
19.4	28.910	5.763	35.303	22.324
19.9	28.918	5.763	35.297	22.316
20.3	28.914	5.763	35.300	22.320
20.7	28.909	5.763	35.303	22.324
21.2	28.915	5.763	35.295	22.316
21.6	28.904	5.763	35.304	22.327
22.1	28.907	5.763	35.299	22.322
22.5	28.901	5.763	35.308	22.331
22.9	28.906	5.762	35.293	22.318
23.3	28.898	5.762	35.299	22.325
23.6	28.895	5.760	35.293	22.322
24.1	28.872	5.757	35.288	22.325
24.3	28.848	5.755	35.287	22.333
24.7	28.825	5.754	35.299	22.349
25.1	28.826	5.754	35.296	22.347
25.4	28.833	5.756	35.308	22.354
25.8	28.846	5.760	35.325	22.362

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profiles in Mixing Zone
(Profile 03 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (C)	Cond (S/m)	Salinity (PSU)	Sigma-t
26.2	28.852	5.761	35.327	22.361
26.5	28.853	5.761	35.323	22.358
26.8	28.857	5.761	35.327	22.359
27.2	28.857	5.762	35.328	22.361
27.6	28.865	5.762	35.325	22.355
28.0	28.856	5.765	35.349	22.377
28.3	28.873	5.767	35.354	22.375
28.6	28.888	5.768	35.352	22.368
28.8	28.891	5.766	35.334	22.354
28.9	28.897	5.768	35.344	22.359
29.1	28.906	5.772	35.364	22.371
29.4	28.916	5.772	35.358	22.363
29.7	28.919	5.773	35.361	22.365
29.9	28.915	5.771	35.350	22.357
30.0	28.914	5.772	35.353	22.360
30.0	28.915	5.772	35.353	22.360
30.2	28.908	5.775	35.380	22.382
30.5	28.913	5.776	35.382	22.383
30.8	28.916	5.775	35.374	22.375
30.9	28.918	5.775	35.377	22.377
31.2	28.917	5.776	35.380	22.379
31.4	28.922	5.775	35.370	22.370
31.6	28.915	5.775	35.374	22.376
31.6	28.918	5.774	35.368	22.370
31.6	28.916	5.775	35.377	22.378
31.4	28.909	5.776	35.386	22.386
31.3	28.917	5.775	35.378	22.378
31.1	28.913	5.776	35.383	22.383
31.1	28.915	5.775	35.376	22.377

Joint Cannery Dilution Study
Non-Tradewind Season
CTD Profile in Mixing Zone
(Profile 04 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
4.7	28.733	5.663	34.744	21.963
5.3	28.742	5.742	35.285	22.367
5.9	28.890	5.759	35.291	22.322
6.3	28.952	5.762	35.268	22.283
7.0	29.014	5.766	35.244	22.245
7.7	29.076	5.769	35.221	22.207
8.2	29.002	5.771	35.290	22.284
8.8	29.000	5.770	35.283	22.279
9.3	28.999	5.770	35.284	22.280
9.8	28.999	5.771	35.290	22.285
10.2	29.001	5.770	35.285	22.280
10.6	28.998	5.771	35.292	22.286
11.1	29.001	5.771	35.290	22.284
11.6	28.999	5.770	35.286	22.282
11.9	29.000	5.769	35.279	22.276
12.2	28.996	5.771	35.291	22.286
12.5	29.001	5.770	35.285	22.280
12.8	29.001	5.771	35.289	22.283
13.2	29.005	5.771	35.290	22.282
13.7	29.001	5.773	35.303	22.293
14.2	29.003	5.775	35.315	22.302
14.6	29.014	5.777	35.318	22.300
15.2	29.016	5.777	35.322	22.303
15.8	29.019	5.777	35.321	22.301
16.2	29.014	5.777	35.324	22.305
16.6	29.016	5.778	35.326	22.306
17.1	29.013	5.777	35.323	22.305
17.4	29.017	5.776	35.313	22.296
17.8	29.012	5.778	35.326	22.307
18.3	28.998	5.778	35.341	22.323
18.7	29.001	5.778	35.339	22.321
19.3	29.004	5.778	35.336	22.317
19.8	29.002	5.778	35.337	22.319
20.2	29.000	5.778	35.338	22.320
20.7	28.995	5.779	35.346	22.328
21.2	28.999	5.778	35.340	22.322
21.7	28.995	5.778	35.343	22.326
22.1	29.000	5.778	35.339	22.321
22.6	28.996	5.778	35.342	22.324
23.1	28.995	5.778	35.341	22.324
23.6	28.987	5.777	35.342	22.328
24.2	28.981	5.777	35.344	22.331

Joint Cannery Dilution Study
Non-Tradewind Season

CTD Profile in Mixing Zone
(Profile 04 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (c)	Cond (S/m)	Salinity (PSU)	Sigma-t
24.6	28.983	5.777	35.339	22.327
25.1	28.977	5.776	35.342	22.331
25.6	28.975	5.776	35.340	22.330
26.2	28.969	5.775	35.340	22.332
26.7	28.956	5.775	35.349	22.343
27.2	28.957	5.775	35.345	22.340
27.8	28.953	5.775	35.346	22.342
28.2	28.954	5.773	35.337	22.335
28.8	28.946	5.773	35.342	22.341
29.3	28.940	5.773	35.347	22.347
29.8	28.941	5.772	35.334	22.337
30.4	28.939	5.772	35.340	22.342
30.9	28.932	5.772	35.343	22.347
31.4	28.927	5.771	35.342	22.348
32.2	28.925	5.772	35.345	22.351
32.3	28.927	5.771	35.337	22.343
32.5	28.919	5.770	35.337	22.347
32.5	28.921	5.771	35.343	22.350
32.3	28.919	5.772	35.352	22.358
31.8	28.930	5.772	35.344	22.348

Joint Cannery Dilution Study
Non-Tradewind Season

CTD Profile in Mixing Zone
(Profile 05 - Raw Data File - Unfiltered)
Date: 2/18/93

Depth (m)	Temp (C)	Cond (S/m)	Salinity (PSU)	Sigma-t
1.0	28.806	0.507	2.513	-2.113
1.2	28.758	1.917	10.504	3.853
1.2	28.768	5.677	34.814	22.004
1.4	28.777	5.653	34.643	21.873
1.8	28.783	5.716	35.072	22.193
2.2	28.782	5.720	35.100	22.214
2.8	28.787	5.721	35.108	22.218
3.3	28.797	5.725	35.129	22.231
3.8	28.810	5.730	35.149	22.241
4.4	28.822	5.741	35.217	22.289
5.0	28.814	5.746	35.259	22.323
5.5	28.798	5.758	35.351	22.398
5.9	28.795	5.755	35.334	22.386
6.3	28.852	5.747	35.239	22.295
6.3	28.791	5.755	35.338	22.390
6.4	28.800	5.752	35.309	22.365
6.8	28.813	5.756	35.325	22.372
7.0	28.796	5.755	35.334	22.385
7.3	28.818	5.760	35.354	22.393
7.4	28.812	5.732	35.161	22.250
7.5	28.825	5.726	35.109	22.207
7.5	28.916	5.738	35.126	22.189
7.5	28.822	5.729	35.137	22.229
7.5	28.876	5.744	35.195	22.254
7.5	28.811	5.739	35.214	22.291
7.5	28.811	5.734	35.173	22.259
7.5	28.811	5.737	35.195	22.276
7.5	28.836	5.749	35.264	22.319

APPENDIX C

CURRENT METER DATA

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data at Mid-Depth in Mixing Zone
(Depth: 100 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231812

Speed (cm/s)	Dir (deg)	Cond (mS/cm)	Temp (C)	Salinity (PSU)	Density (Kg/m^3)
15.1	95	57.00	28.68	35.04	1022.21
19.7	283	57.00	28.72	35.01	1022.16
2/16/93	**17:23**				
19.3	276	57.00	28.68	35.04	1022.21
18.0	53	57.00	28.72	35.01	1022.16
18.9	253	57.00	28.72	35.01	1022.16
2/16/93	**17:53**				
17.9	41	57.00	28.72	35.01	1022.16
16.6	54	57.00	28.72	35.01	1022.16
19.3	263	57.00	28.72	35.01	1022.16
2/16/93	**18:23**				
17.3	37	57.00	28.68	35.04	1022.21
8.2	72	57.00	28.68	35.04	1022.21
17.7	240	57.00	28.68	35.04	1022.21
2/16/93	**18:53**				
15.7	53	56.80	28.58	34.98	1022.19
15.5	51	56.80	28.53	35.01	1022.23
16.3	54	56.90	28.58	35.05	1022.24
2/16/93	**19:23**				
17.4	224	56.70	28.48	34.98	1022.22
17.0	225	56.90	28.58	35.05	1022.24
17.6	29	56.80	28.53	35.01	1022.23
2/16/93	**1953**				
18.3	37	56.80	28.58	34.98	1022.19
19.3	42	56.90	28.63	35.01	1022.20
15.7	56	56.90	28.68	34.97	1022.15
2/16/93	**20:23**				
17.5	199	57.00	28.68	35.04	1022.21
5.1	283	57.00	28.63	35.08	1022.25
18.5	23	57.00	28.72	35.01	1022.16
2/16/93	**20:53**				
19.7	30	57.00	28.68	35.04	1022.21
7.4	88	57.00	28.68	35.04	1022.21
17.6	201	57.00	28.68	35.04	1022.21
2/16/93	**21:23**				
9.8	266	57.00	28.68	35.04	1022.21
17.9	18	57.00	28.68	35.04	1022.21
13.4	52	56.90	28.63	35.01	1022.20
2/16/93	**21:53**				
17.8	192	56.90	28.63	35.01	1022.20

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data at Mid-Depth in Mixing Zone
(Depth: 100 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231812

Speed (cm/s)	Dir (deg)	Cond (mS/cm)	Temp (C)	Salinity (PSU)	Density (Kg/m^3)
17.9	200	56.90	28.63	35.01	1022.20
16.3	225	56.80	28.58	34.98	1022.19
2/16/93	**22:23**				
17.8	335	57.00	28.58	35.12	1022.29
17.5	341	56.80	28.58	34.98	1022.19
17.9	347	56.80	28.58	34.98	1022.19
2/16/93	**22:53**				
18.6	358	56.80	28.58	34.98	1022.19
16.6	126	56.80	28.53	35.01	1022.23
18.1	155	56.80	28.53	35.01	1022.23
2/16/93	**23:23**				
18.2	165	56.80	28.53	35.01	1022.23
16.5	170	56.90	28.63	35.01	1022.20
16.8	177	56.90	28.58	35.05	1022.24
2/16/93	**23:53**				
16.4	193	56.90	28.63	35.01	1022.20
15.6	266	57.00	28.68	35.04	1022.21
20.5	330	56.90	28.63	35.01	1022.20
2/17/93	**0:23**				
21.4	342	57.00	28.68	35.04	1022.21
21.1	342	57.00	28.68	35.04	1022.21
20.4	11	57.00	28.68	35.04	1022.21
2/17/93	**0:53**				
15.3	122	57.00	28.68	35.04	1022.21
14.5	160	57.00	28.68	35.04	1022.21
14.1	162	57.00	28.68	35.04	1022.21
2/17/93	**1:23**				
15.1	195	57.00	28.68	35.04	1022.21
20.5	292	57.00	28.68	35.04	1022.21
20.7	317	57.00	28.68	35.04	1022.21
2/17/93	**1:53**				
21.2	329	57.00	28.68	35.04	1022.21
20.4	336	57.00	28.68	35.04	1022.21
19.6	352	57.00	28.68	35.04	1022.21
2/17/93	**2:23**				
20.1	9	57.00	28.68	35.04	1022.21
16.3	96	57.00	28.68	35.04	1022.21
15.0	124	57.00	28.68	35.04	1022.21
2/17/93	**2:53**				
14.3	139	57.00	28.68	35.04	1022.21
14.8	147	57.00	28.72	35.01	1022.16

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data at Mid-Depth in Mixing Zone
(Depth: 100 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231812

Speed (cm/s)	Dir (deg)	Cond (mS/cm)	Temp (C)	Salinity (PSU)	Density (Kg/m^3)
15.2	175	57.00	28.68	35.04	1022.21
2/17/93	**3:23**				
15.6	179	57.00	28.72	35.01	1022.16
19.8	249	57.00	28.68	35.04	1022.21
19.4	284	57.00	28.72	35.01	1022.16
2/17/93	**3:53**				
19.5	293	57.00	28.68	35.04	1022.21
18.8	307	57.00	28.68	35.04	1022.21
18.1	315	56.90	28.72	34.94	1022.11
2/17/93	**4:23**				
18.2	320	56.90	28.68	34.97	1022.15
17.8	325	56.90	28.68	34.97	1022.15
17.8	331	56.90	28.68	34.97	1022.15
2/17/93	**4:53**				
18.0	331	56.90	28.68	34.97	1022.15
17.9	344	57.00	28.72	35.01	1022.16
17.3	341	56.90	28.68	34.97	1022.15
2/17/93	**5:23**				
17.4	338	57.00	28.72	35.01	1022.16
17.5	346	56.90	28.68	34.97	1022.15
16.7	354	56.90	28.68	34.97	1022.15
2/17/93	**5:53**				
17.9	51	56.90	28.63	35.01	1022.20
18.7	109	56.80	28.63	34.94	1022.15
18.3	118	56.90	28.63	35.01	1022.20
2/17/93	**6:23**				
18.8	125	56.90	28.63	35.01	1022.20
17.9	125	56.80	28.63	34.94	1022.15
17.9	130	56.90	28.68	34.97	1022.15
2/17/93	**6:53**				
17.3	139	56.90	28.68	34.97	1022.15
17.8	138	57.00	28.68	35.04	1022.21
17.8	132	56.90	28.68	34.97	1022.15
2/17/93	**7:23**				
18.4	134	56.90	28.68	34.97	1022.15
18.5	137	56.90	28.68	34.97	1022.15
19.1	136	56.90	28.68	34.97	1022.15
2/17/93	**7:53**				
19.0	137	57.00	28.68	35.04	1022.21
19.3	140	56.90	28.63	35.01	1022.20
18.4	139	56.90	28.63	35.01	1022.20

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data at Mid-Depth in Mixing Zone
(Depth: 100 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231812

Speed (cm/s)	Dir (deg)	Cond (mS/cm)	Temp (C)	Salinity (PSU)	Density (Kg/m^3)
2/17/93	**8:23**				
18.7	142	56.90	28.63	35.01	1022.20
18.5	144	56.90	28.63	35.01	1022.20
19.2	144	56.90	28.63	35.01	1022.20
2/17/93	**8:53**				
18.3	141	56.90	28.63	35.01	1022.20
18.3	141	56.90	28.63	35.01	1022.20
18.3	139	56.90	28.63	35.01	1022.20
2/17/93	**9:23**				
17.9	153	56.90	28.63	35.01	1022.20
17.4	157	56.90	28.63	35.01	1022.20
17.7	158	56.90	28.63	35.01	1022.20
2/17/93	**9:53**				
17.9	151	56.80	28.63	34.94	1022.15
18.0	145	56.90	28.63	35.01	1022.20
19.0	148	56.80	28.63	34.94	1022.15
2/17/93	**10:23**				
18.1	264	56.80	28.63	34.94	1022.15
17.6	271	56.90	28.63	35.01	1022.20
17.7	263	57.00	28.68	35.04	1022.21
2/17/93	**10:53**				
17.9	254	56.90	28.63	35.01	1022.20
18.1	260	56.90	28.68	34.97	1022.15
17.6	269	56.90	28.68	34.97	1022.15
2/17/93	**11:23**				
17.3	265	56.80	28.68	34.90	1022.10
16.6	273	56.90	28.68	34.97	1022.15
16.3	276	56.80	28.68	34.90	1022.10
2/17/93	**11:53**				
16.7	282	56.90	28.68	34.97	1022.15
17.9	290	57.00	28.72	35.01	1022.16
18.3	286	56.90	28.68	34.97	1022.15
2/17/93	**12:23**				
18.5	283	56.90	28.68	34.97	1022.15
19.3	283	56.90	28.68	34.97	1022.15
20.9	289	57.00	28.72	35.01	1022.16
2/17/93	**12:53**				
20.5	289	57.00	28.72	35.01	1022.16
20.4	291	57.00	28.77	34.97	1022.12
20.1	291	57.00	28.77	34.97	1022.12
2/17/93	**13:23**				

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data at Mid-Depth in Mixing Zone
(Depth: 100 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231812

Speed (cm/s)	Dir (deg)	Cond (mS/cm)	Temp (C)	Salinity (PSU)	Density (Kg/m^3)
19.8	285	57.00	28.77	34.97	1022.12
19.8	288	57.00	28.77	34.97	1022.12
19.6	270	57.00	28.77	34.97	1022.12
2/17/93	**13:53**				
18.6	279	56.80	28.68	34.90	1022.10
19.0	278	56.80	28.68	34.90	1022.10
19.8	271	56.80	28.68	34.90	1022.10
2/17/93	**14:23**				
19.2	271	56.80	28.68	34.90	1022.10
19.2	278	56.90	28.72	34.94	1022.11
18.6	277	56.80	28.68	34.90	1022.10
2/17/93	**14:53**				
18.4	270	56.80	28.68	34.90	1022.10
18.2	271	56.80	28.68	34.90	1022.10
18.8	271	56.90	28.72	34.94	1022.11
2/17/93	**15:23**				
18.8	270	56.80	28.68	34.90	1022.10
17.9	277	56.80	28.68	34.90	1022.10
17.6	273	56.90	28.68	34.97	1022.15
2/17/93	**15:53**				
17.9	284	56.80	28.63	34.94	1022.15
17.9	276	56.80	28.63	34.94	1022.15
18.0	269	56.80	28.68	34.90	1022.10
2/17/93	**16:23**				
18.4	268	56.80	28.68	34.90	1022.10
17.8	266	56.80	28.68	34.90	1022.10
18.4	271	56.80	28.72	34.87	1022.06
2/17/93	**16:53**				
18.2	272	56.80	28.68	34.90	1022.10

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data Near Bottom in Mixing Zone
(Depth: 170 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231813

Speed (cm/sec)	Dir (deg)	Cond (mS/cm)	Temp (C)	Depth (meters)	Salinity (PSU)	Density (Kg/m^3)
2/16/93	**16:53**					
2.4	35	57.60	28.33	51.32	35.70	1023.04
2.4	48	57.50	28.33	51.32	35.63	1022.98
2.4	35	57.50	28.33	51.32	35.63	1022.98
2/16/93	**17:23**					
1.1	45	57.50	28.33	51.25	35.63	1022.98
1.5	344	57.50	28.33	51.25	35.63	1022.98
2.8	356	57.50	28.33	51.18	35.63	1022.98
2/16/93	**17:53**					
3.5	336	57.50	28.33	51.18	35.63	1022.98
2.7	343	57.50	28.33	51.18	35.63	1022.98
4	323	57.40	28.33	51.18	35.56	1022.93
2/16/93	**18:23**					
3.5	317	57.40	28.33	51.11	35.56	1022.93
3.2	325	57.40	28.28	51.11	35.60	1022.97
3.5	329	57.40	28.28	51.05	35.60	1022.97
2/16/93	**18:53**					
2.7	343	57.40	28.28	51.05	35.60	1022.97
4.8	315	57.40	28.28	51.05	35.60	1022.97
4.4	344	57.40	28.28	50.98	35.60	1022.97
2/16/93	**19:23**					
2.7	318	57.40	28.33	50.98	35.56	1022.93
2.4	5	57.40	28.33	50.98	35.56	1022.93
5	326	57.40	28.24	50.91	35.63	1023.02
2/16/93	**19:53**					
2.4	318	57.40	28.24	50.84	35.63	1023.02
0.3	135	57.40	28.33	50.84	35.56	1022.93
0	0	57.40	28.33	50.84	35.56	1022.93
2/16/93	**20:23**					
0.8	180	57.40	28.33	50.77	35.56	1022.93
1	217	57.40	28.33	50.77	35.56	1022.93
1.5	157	57.40	28.33	50.77	35.56	1022.93
2/16/93	**20:53**					
0.8	270	57.40	28.38	50.70	35.52	1022.88
0.6	162	57.50	28.38	50.70	35.59	1022.94
0.4	243	57.40	28.38	50.70	35.52	1022.88
2/16/93	**21:23**					
0	0	57.40	28.38	50.70	35.52	1022.88
1.4	180	57.40	28.33	50.64	35.56	1022.93
0.6	198	57.40	28.33	50.64	35.56	1022.93

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data Near Bottom in Mixing Zone
(Depth: 170 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231813

Speed (cm/sec)	Dir (deg)	Cond (mS/cm)	Temp (C)	Depth (meters)	Salinity (PSU)	Density (Kg/m^3)
2/16/93	**21:53**					
0.7	124	57.40	28.33	50.64	35.56	1022.93
0.4	90	57.40	28.33	50.64	35.56	1022.93
0.4	153	57.40	28.33	50.64	35.56	1022.93
2/16/93	**22:23**					
0.6	252	57.40	28.33	50.64	35.56	1022.93
1.1	225	57.40	28.33	50.57	35.56	1022.93
1	270	57.40	28.33	50.64	35.56	1022.93
2/16/93	**22:53**					
0.7	236	57.40	28.38	50.57	35.52	1022.88
0.4	270	57.40	28.38	50.64	35.52	1022.88
0.4	0	57.40	28.38	50.64	35.52	1022.88
2/16/93	**23:23**					
0.7	214	57.40	28.38	50.64	35.52	1022.88
1	101	57.40	28.33	50.64	35.56	1022.93
0.7	34	57.40	28.38	50.64	35.52	1022.88
2/16/93	**23:53**					
1.4	82	57.40	28.33	50.70	35.56	1022.93
1.8	77	57.40	28.33	50.70	35.56	1022.93
1.6	97	57.40	28.33	50.70	35.56	1022.93
2/17/93	**0:23**					
0.7	146	57.40	28.38	50.70	35.52	1022.88
0.9	117	57.40	28.38	50.77	35.52	1022.88
0.4	90	57.40	28.38	50.77	35.52	1022.88
2/17/93	**0:53**					
0.9	117	57.40	28.38	50.77	35.52	1022.88
0.2	90	57.40	28.38	50.84	35.52	1022.88
0.6	225	57.40	28.43	50.84	35.49	1022.84
2/17/93	**1:23**					
1.2	90	57.40	28.43	50.91	35.49	1022.84
0.7	304	57.50	28.38	50.91	35.59	1022.94
0.9	243	57.40	28.33	50.91	35.56	1022.93
2/17/93	**1:53**					
0.6	0	57.40	28.43	50.98	35.49	1022.84
1.6	353	57.40	28.43	51.05	35.49	1022.84
1.3	342	57.40	28.38	50.98	35.52	1022.89
2/17/93	**2:23**					
1.8	333	57.40	28.43	51.05	35.49	1022.84
1.5	286	57.50	28.43	51.05	35.56	1022.89
1.6	277	57.50	28.43	51.11	35.56	1022.89
2/17/93	**2:53**					

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data Near Bottom in Mixing Zone
(Depth: 170 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231813

Speed (cm/sec)	Dir (deg)	Cond (mS/cm)	Temp (C)	Depth (meters)	Salinity (PSU)	Density (Kg/m^3)
0.8	284	57.40	28.43	51.11	35.49	1022.84
1.6	0	57.40	28.38	51.11	35.52	1022.89
1.8	6	57.40	28.43	51.11	35.49	1022.84
2/17/93	**3:23**					
0.6	45	57.50	28.48	51.18	35.52	1022.85
0.2	0	57.50	28.48	51.11	35.52	1022.85
1.2	0	57.50	28.43	51.18	35.56	1022.89
2/17/93	**3:53**					
1.4	352	57.50	28.53	51.18	35.48	1022.81
0.4	243	57.50	28.48	51.18	35.52	1022.85
1.6	180	57.50	28.53	51.18	35.48	1022.81
2/17/93	**4:23**					
0.8	0	57.60	28.53	51.25	35.55	1022.86
1.8	13	57.50	28.43	51.25	35.56	1022.89
2.2	333	57.50	28.43	51.18	35.56	1022.89
2/17/93	**4:53**					
1.8	311	57.50	28.48	51.18	35.52	1022.85
1.1	292	57.50	28.48	51.18	35.52	1022.85
0.4	243	57.50	28.48	51.18	35.52	1022.85
2/17/93	**5:23**					
0.6	315	57.50	28.48	51.18	35.52	1022.85
2.8	0	57.50	28.48	51.18	35.52	1022.85
2.4	0	57.50	28.48	51.18	35.52	1022.85
2/17/93	**5:53**					
3.3	327	57.50	28.48	51.18	35.52	1022.85
1.2	351	57.50	28.48	51.11	35.52	1022.85
3.3	317	57.60	28.53	51.11	35.55	1022.86
2/17/93	**6:23**					
2.3	329	57.50	28.48	51.11	35.52	1022.85
3.3	322	57.60	28.48	51.05	35.59	1022.9
2.7	324	57.60	28.53	51.05	35.55	1022.86
2/17/93	**6:53**					
2.6	328	57.60	28.53	51.05	35.55	1022.86
3.3	327	57.60	28.53	51.05	35.55	1022.86
2.5	331	57.60	28.53	50.98	35.55	1022.86
2/17/93	**7:23**					
3.5	347	57.60	28.53	50.91	35.55	1022.86
3.9	345	57.60	28.58	50.91	35.52	1022.81
2.8	356	57.60	28.58	50.91	35.52	1022.81
2/17/93	**7:53**					
2.6	4	57.60	28.58	50.84	35.52	1022.81

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data Near Bottom in Mixing Zone
(Depth: 170 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231813

Speed (cm/sec)	Dir (deg)	Cond (mS/cm)	Temp (C)	Depth (meters)	Salinity (PSU)	Density (Kg/m^3)
2.6	0	57.60	28.53	50.84	35.55	1022.86
0.7	326	57.60	28.48	50.84	35.59	1022.9
2/17/93	**8:23**					
1.3	288	57.60	28.53	50.84	35.55	1022.86
0.8	270	57.60	28.53	50.77	35.55	1022.86
1.4	270	57.60	28.53	50.77	35.55	1022.86
2/17/93	**8:53**					
1	281	57.60	28.53	50.77	35.55	1022.86
2.4	318	57.60	28.53	50.70	35.55	1022.86
3.7	324	57.60	28.48	50.70	35.59	1022.9
2/17/93	**9:23**					
3.6	322	57.60	28.53	50.70	35.55	1022.86
3.1	310	57.60	28.53	50.70	35.55	1022.86
3.1	328	57.60	28.53	50.64	35.55	1022.86
2/17/93	**9:53**					
3.6	322	57.60	28.53	50.64	35.55	1022.86
3	318	57.60	28.53	50.57	35.55	1022.86
2	307	57.60	28.53	50.57	35.55	1022.86
2/17/93	**10:23**					
1.6	284	57.60	28.53	50.64	35.55	1022.86
1.6	270	57.60	28.53	50.64	35.55	1022.86
1.2	261	57.60	28.53	50.64	35.55	1022.86
2/17/93	**10:53**					
0.6	270	57.60	28.53	50.64	35.55	1022.86
0.2	180	57.60	28.53	50.64	35.55	1022.86
0.6	0	57.60	28.53	50.64	35.55	1022.86
2/17/93	**11:23**					
0.6	18	57.50	28.53	50.64	35.48	1022.8
0.6	45	57.60	28.53	50.64	35.55	1022.86
0.7	56	57.60	28.53	50.64	35.55	1022.86
2/17/93	**11:53**					
0.6	72	57.60	28.53	50.64	35.55	1022.86
0.6	18	57.60	28.53	50.70	35.55	1022.86
0.8	76	57.60	28.53	50.77	35.55	1022.86
2/17/93	**12:23**					
1.8	90	57.60	28.53	50.70	35.55	1022.86
2.1	119	57.60	28.53	50.77	35.55	1022.86
1.9	148	57.60	28.58	50.77	35.52	1022.81
2/17/93	**12:53**					
3.1	130	57.60	28.63	50.84	35.48	1022.77
3.6	128	57.60	28.58	50.84	35.52	1022.81

Joint Cannery Dye Study
Non-Tradewind Season

S4 Current Meter Data Near Bottom in Mixing Zone
(Depth: 170 ft - Raw Data File - Unfiltered)
Date: 2/16-17/1993
InterOcean Systems, Inc. Model S4 Current Meter #08231813

Speed (cm/sec)	Dir (deg)	Cond (mS/cm)	Temp (C)	Depth (meters)	Salinity (PSU)	Density (Kg/m^3)
1.8	84	57.60	28.53	50.84	35.55	1022.86
2/17/93	**13:23**					
1.8	90	57.60	28.53	50.98	35.55	1022.86
2.2	80	57.60	28.53	50.91	35.55	1022.86
2.3	52	57.60	28.53	50.98	35.55	1022.86
2/17/93	**13:53**					
2	45	57.50	28.53	51.05	35.48	1022.81
2.3	38	57.60	28.53	51.05	35.55	1022.86
2.3	75	57.60	28.53	51.05	35.55	1022.86
2/17/93	**14:23**					
2.2	85	57.60	28.53	51.11	35.55	1022.86
3	90	57.60	28.53	51.11	35.55	1022.86
3.8	90	57.60	28.58	51.18	35.52	1022.82
2/17/93	**14:53**					
3.2	86	57.60	28.58	51.18	35.52	1022.82
3.7	112	57.60	28.53	51.18	35.55	1022.86
4.2	121	57.60	28.58	51.25	35.52	1022.82
2/17/93	**15:23**					
4.7	118	57.60	28.58	51.25	35.52	1022.82
2.3	128	57.60	28.58	51.25	35.52	1022.82
2.2	153	57.60	28.58	51.25	35.52	1022.82
2/17/93	15:53					
0.7	124	57.60	28.58	51.25	35.52	1022.82
0.6	90	57.60	28.58	51.32	35.52	1022.82
1.2	121	57.60	28.63	51.25	35.48	1022.77
2/17/93	**16:23**					
1.1	135	57.60	28.58	51.32	35.52	1022.82
1.6	90	57.60	28.58	51.32	35.52	1022.82
2.8	90	57.60	28.58	51.32	35.52	1022.82
2/17/93	**16:53**					
3	90	57.60	28.58	51.32	35.52	1022.82

ADDENDUM

JOINT CANNERY OUTFALL DILUTION STUDY PLAN

JOINT CANNERY OUTFALL
DILUTION STUDY PLAN

Including Response to Comments

for

StarKist Samoa, Inc.

and

VCS Samoa Packing Company

to comply with NPDES Permits

AS0000019

AS0000027

December 30, 1992

prepared by

CH2M HILL

JOINT CANNERY OUTFALL DILUTION STUDY PLAN

The joint cannery dilution study plan describes the approach for conducting a wastefield dilution study (dye study) of the effluent discharged from the Joint Cannery Outfall located in Pago Pago Harbor, American Samoa. StarKist Samoa, Inc. and VCS Samoa Packing Company operate and discharge through the outfall. A joint dye study is required as a permit condition under the separate NPDES permits issued to each cannery.

A draft study plan was prepared for review by USEPA and ASEPA. The review found the draft study plan "basically acceptable" with a request to address concerns expressed by Dr. Walter Frick of the USEPA. The draft study plan (Agency Review Draft, 29 October 1992) together with the response to comments provided below, consists of the final dilution study plan. The draft study plan is Attachment 1 to this report and the comments on the draft plan are provided in Attachment 2.

RESPONSE TO COMMENTS

All comments on the draft study plan were provide by Dr. Frick in a memo to Janet Hashimoto, Region IX, USEPA dated 25 November 1992. The following are the responses to his comments and concerns with reference to each paragraph of his memorandum (Attachment 2):

Page -1 - Paragraph 1: He finds the draft plan basically acceptable. His comments express his concerns that the results of the dye study provide information and data appropriate for assessing compliance with permit conditions and American Samoa Water Quality Standards. This is the intent of the dye study. The project staff appreciates Dr. Frick's concerns as discussed below.

Paragraph 2: CH2M HILL project staff are well aware of the limitations, pitfalls, and difficulties of performing field dye studies. The project team that will conduct the study has done 25 to 30 dye studies over the past few years. These dye studies have been conducted under a wide range of environmental conditions in virtually every type of estuarine setting. The location and tracking of the of a dye plume in the manner described is routinely accomplished by project staff. As pointed out by Dr. Frick, there is no practical alternative to the method proposed.

Paragraph 3: Significant overestimates of the dilution are not anticipated by CH2M HILL project staff. Dr. Frick mentions three areas of concern for overestimating the dilution: water depth variation, vertical current shear, and internal waves. He is concerned that these factors might change the depth and/or location of the dye concentration maximum and the drogue would no longer be an indicator of the depth and/or location of the concentration maximum. The field data collection techniques, as discussed under *Paragraph 4* below, will account for any changes in depth of maximum concentration. With respect to specific items, our understanding of the concerns is as follows:

- The diffuser is located in about 180 feet of water and, based on available current data, it is anticipated that the plume will move approximately parallel to the depth contours. If the plume moves in this fashion, or toward the center of the harbor (southwest), the depth of water will not change significantly. However, if the plume moves toward the reef there may be some significant topographic effects on the plume and the drogue may not follow the maximum dye concentration. Under most conditions the plume will remain submerged, as predicted by dilution models and verified by observation. On encountering the reef wall the plume will be steered shore parallel in shallower water (but not on the reef itself). This could change the depth of maximum dye concentration. Proposed vertical profiling (see Paragraph 4 below) will account for any such behavior and the concentration maximum will be detected and recorded.

- Currents are relatively weak in Pago Pago Harbor and, although vertical current shear could be a factor in determining the plume maximum concentration location, it is not likely that this will be significant. The existence of any significant effect should be reflected in the current meter records above and below the initial trapping depth. The proposed vertical profiling at the mixing zone boundary (see Paragraph 4 below) will result in a record that includes the maximum dye concentrations even if the drogue does not follow the maximum concentration to the mixing zone boundary.

- Internal wave motion or harbor oscillations could result in the vertical or horizontal movement of the plume centerline. It is not anticipated that amplitudes would be sufficient to seriously affect the measurements. However, the proposed vertical profiling (see Paragraph 4 below) will be able to determine if such an effect exists and determine the dye concentration maximum.

All of the items listed above are valid concerns. CH2M HILL's experience and site specific knowledge indicates that the effects will not be significant in terms of defining concentration maximums. Even under conditions under where effects become important, the proposed sampling technique discussed below will be sufficient to indicate the presence of the effects and determine the actual dye concentration maximum within limits acceptable for the purposes of the dye study.

Page 2 - Paragraph 4: During the collection of field data (dye concentrations) continuous vertical profiles through the plume, using a submerged pump and flow-through operation of the fluorometer, will be made following a drogue. The depth and concentration of the dye maximum will be observable with on board instruments. Therefore, any differences in depth of the drogue and the dye concentration maximum will be obvious and the maximum (with depth) dye concentration will be recorded. This avoids, to the extent possible, most of the concerns raised by Dr. Frick.

In addition, at the mixing zone boundary, continuous vertical profiles will be made at and on both sides of the drogue crossing point. This will be done at a sufficient number of stations along the mixing zone boundary to provide confidence that the actual plume centerline and maximum dye concentration have been determined. In addition to, or in lieu of, repeated vertical profiles, horizontal transects of dye concentration at the depth of maximum dye concentration will be made across the width of the plume.

The procedures described above are standard procedures during CH2M HILL dye studies. The intent is to take whatever action is necessary to define the minimum dilution (maximum dye concentration) at the appropriate location. The attached draft dilution study plan should be interpreted as consistent with this objective and to include the procedures described above.

Paragraph 5: The density gradients used in the previous modeling were based on examination of available data, collected during different seasons, by CH2M HILL and others. Except for rainfall-runoff events which can create a surface layer, density gradients are generally not very "strong" and the "stronger gradient" used for the model is representative. Since the plume from the new outfall diffuser is usually trapped well below the surface, the existence of thin surface layers caused by rainfall events will not directly effect the plume dilution or behavior. Density gradients measured during the time of the dye study will be reported.

Paragraph 6: The modeling used to define the mixing zone did account for "background" concentrations. The modeling effort, which is summarized in the Technical Memorandum referred to in paragraph 5 of the comment letter, accounted for:

- Background concentrations (typical open coast concentrations) expected in the absence of point and nonpoint source loadings in the harbor

- Ambient long term average concentrations (outside the immediate area of discharge) which include background and the effects of all point and nonpoint sources loadings in the harbor, including the canneries (i.e. entrainment and re-entrainment phenomena)

- Effluent plume concentrations during initial dilution calculated by accounting for ambient concentrations (using ambient water for dilution and calculation of an effective dilution)

- Effluent plume concentrations during subsequent dilution calculated by accounting for ambient concentrations (using ambient water for dilution and calculation of an effective dilution)

The mixing zone boundary was established by using a set of complimentary models and considering the interaction of the discharge with the existing concentrations in the ambient receiving water. The modeling is described in more detail in the *Engineering and Environmental Feasibility Evaluation of Waste Disposal Alternatives* prepared for StarKist by CH2M HILL in 1991. The approach used generally follow that described in *Dilution Models for Effluent Discharge* by Baumgartmer et al.

Water quality measurements in Pago Pago harbor in recent years, referred to by Dr. Frick, were made when the both canneries discharged into the inner harbor. The initiation of high strength waste segregation resulted in significant improvements in water quality. However, water quality standards were still exceed throughout much of the harbor, especially in the inner harbor. The present location of the discharge in the outer harbor was selected, based on model predictions, to improve water quality throughout the harbor and meet water quality standards (except within a designated mixing zone). This new outfall has been operating since February of 1992 and indications are that water quality standards are now being met. CH2M HILL has not done a review of monitoring data since the new outfall became operational, but this review, and model verification, will be done as a permit condition (see Sections E and J of the NPDES permits for both canneries).

Paragraph 7: The circulation pattern described, of wind driven inflow at the surface and a return outflow at depth, was based on available current meter and drogue tracking data and is a description of typical long term (net) flow patterns. More description is provided in the Feasibility Study report referenced above. Outflow on the surface in response to rainfall-runoff events is observed and is superimposed on the long term patterns. The dye study combined with the long term monitoring data will provide a better picture of the flow patterns in the harbor. It is unlikely that a single dye study, by itself, will directly provide much new insight into the overall long term net flow characteristics of the system. The model verification study will use both long term monitoring data and dye study data to address this concern.

Paragraph 8: Dr. Frick's comments were appropriate and useful in review of the dye study plan, and other studies required as permit conditions. The above descriptions were intended to address each of the concerns expressed in Dr. Frick's memorandum. The description of field techniques in Paragraph 4 above constitutes the only revision or addition to the text of the draft dilution study plan. Paragraphs 5 and 6 do not directly address the objectives of the dye study but are useful and important points that will be addressed in another study under the existing NPDES permits.

ATTACHMENT 1

Draft Dye Study Plan

AGENCY REVIEW DRAFT

JOINT CANNERY OUTFALL DILUTION STUDY PLAN

for

StarKist Samoa, Inc.

and

VCS Samoa Packing Company

to comply with NPDES Permits

AS0000019

AS0000027

October 29, 1992

prepared by

CH2M HILL

JOINT CANNERY OUTFALL DILUTION STUDY PLAN

INTRODUCTION

This dilution study plan describes the approach proposed for conducting a wastefield dilution study (dye study) of the effluent discharged from the Joint Cannery Outfall (JCO) located in Pago Pago Harbor, American Samoa. StarKist Samoa, Inc. (SKS) and VCS Samoa Packing Company (VCS) operate and discharge through the outfall. The study plan describes the data to be collected and methods proposed to collect the data. The quality control and quality assurance procedures and the types of data processing are also described.

PURPOSE

The purpose of this study plan is to propose a joint cannery dye study, consisting of two field efforts, to USEPA and ASEPA for approval. The purpose of the proposed dye study is collect the necessary data to better understand the fate of the effluent plume. The data to be collected are intended to provide direct evidence of plume behavior and to provide information to be used to verify model predictions of dilution and dispersion of the wastefield.

BACKGROUND

The canneries began discharging their treated wastewater, after high strength segregation, into the outer harbor in February of 1992. This is a new outfall that replaces individual inner harbor discharges. Newly issued NPDES permits are based on an approved zone of mixing. The size and location of the zone of mixing was based on environmental and engineering studies which included model predictions.

The NPDES permits issued to each cannery require two dye or tracer field studies. These studies are described in Part F of permit numbers AS0000019 and AS0000027. The effective dates of the permits are 27 October 1992. The permit condition is identical for both canneries and reads:

> *Within one week of the effective date of this permit, the permittee shall submit a plan to the ASEPA and EPA to perform dye and/or tracer studies in order to better understand the fate of the effluent plume. The permittee shall perform these studies twice for one year (once during each of the two primary seasons of the year) and submit its findings 30 days after conducting*

> *each study. The date of the first study must be approved by USEPA and ASEPA and shall occur at the earliest possible time a distinct oceanographic season is in effect and no later than four months of the effective date of the permit.*

In the response to comments on the draft NPDES permits EPA indicated that the first study "is to occur no later than six months after the issuance of this permit." This plan proposes the first field study be conducted in February 1993 and the second in September 1993. Therefore the first field study is proposed to be within four months of the effective date of the permit.

APPROACH

This study is designed to obtain accurate measurements of dye injected and completely mixed into the effluent (wastewater tracer) and released through the outfall diffuser. The dye study is intended to provide direct measurements of nearfield and farfield dilution. Dilution of the wastewater will be determined by continuously injecting fluorescent dye into the discharge at a controlled rate for a period of approximately 13 hours. The horizontal and vertical distribution of the resulting plume will be measured throughout a tidal cycle during daylight hours. Environmental parameters that influence plume buoyancy and trajectory will also be measured and recorded including: current speed and direction, tide height, water temperature, conductivity (salinity), and wind speed and direction. Dilution ratios and effluent concentrations will be determined at the edge of the designated zone of mixing, within the zone of mixing, and at various distances beyond the zone of mixing.

The study will be performed during the two distinct oceanographic seasons, tradewind and non-tradewind, and include, to the extent possible, periods of critical receiving water conditions (such as low slack water and tide reversal) that represent the "worst case" for effluent dilutions. However, the circulation and currents in Pago Pago are largely wind driven, and the times of critical periods are not completely predictable. The data collected during the dye study will be used to verify previous modeling in a separate study (Part J in the NPDES permits). The models used were applied to critical conditions, and verification of the models with dye study data will provide the desired confidence in wastefield dilution and transport predictions for worst case conditions.

Field data will be processed and presented in graphical and tabular formats and described in dilution study reports. An interim report will be written and submitted within 30 days of the first dye study and a final report within 30 days of the second study. Supporting data will be included in the report appendices. The data analysis will include evaluation of the measured dilutions and concentrations in terms of compliance with American Samoa water quality standards.

STUDY PERIODS

It is desirable to conduct dilution studies during "critical conditions". Critical conditions are defined as those environmental conditions that result in the lowest initial dilution for the effluent flow of interest. The most important environmental parameters involved are current speed and direction, water depth, and density variations in the vertical direction. For the JCO in Pago Pago Harbor critical conditions are not easily targeted since the currents are generally wind driven, the outfall is deep so the plume is generally trapped below the surface, and the receiving water density gradients are small.

The dye study will be conducted over a tidal cycle to evaluate, if possible, the effect of tidal variations. Variations of environmental parameters over a tidal cycle are small. Most of the environmental variability is found on a seasonal basis. Two distinct oceanographic seasons represent the extremes in current patterns and density structure in Pago Pago Harbor. The non-tradewind season is most pronounced in January and February. The first dye study is targeted for the first week in February. This schedule may change but the study will be conducted within the January-February window. The tradewind season is most pronounced in May through October. August is, on the average, the most intense of the tradewind months and the middle of August is the target date for the second dye study.

STUDY METHODS

The elements of a dye study include injecting dye into the effluent stream to produce known initial concentrations and measuring the subsequent concentrations of dye in the receiving water. The environmental parameters important to the dilution and dispersion processes are also measured to provide a basis for interpreting the results and characterizing the behavior of the wastefield plume. This section of the study plan describes the methods proposed to carry out the elements of the study.

DYE INJECTION

A 20 percent aqueous solution of Rhodamine WT dye will be used as the tracer. This dye is a fluorescent, water soluble, biodegradable tracer that can be accurately measured in extremely small concentrations, typically less than 0.2 part per billion (ppb). A peristaltic, variable-rate laboratory pump (or a variable stroke injector pump) will be used for dye injection. The pump will be calibrated by direct volumetric measurement of dye pumped before and after the study.

Dye Injection Location

Dye will be injected at a point to be determined, at either SKS or VCS, based on available and appropriate injection locations. The final decision on a dye injection point will be determined on site during field mobilization. Effluent flow rates for both canneries will be monitored during the dye study to facilitate any required adjustments in dye injection rate. Initial dye concentrations will be measured from samples extracted from the outfall pipeline through a sampling tap to be installed downstream of the VCS inflow. The sampling port will be a sufficiently far downstream of the injection point to allow the dye to become well mixed with the effluent.

Dye Injection Time

Dye injections will occur over a tidal cycle (about 13 hours) to provide for direct measurements of nearfield and farfield dilutions, and wastefield overlap, if any, due to tidal reversals. Dye injection will have to begin prior to field measurements of the effluent plume. Travel time in the pipe is just over one-half hour for maximum (permitted) flows and about 1.5 hours for low (99-percentile) flows. Therefore, dye injection will start approximately an hour prior to the start of field measurements.

Dye Injection Rate

Dye will be injected at a rate sufficient to produce a discharge concentration of approximately 2 parts per million (ppm) or higher. Assuming a practical dye detection limit of 1 ppb above background, it will be possible to accurately map the dye plume to a point where it has been diluted to 2000:1 or more. Background fluorescence and effluent characteristics, determined during fluorometer calibration, may indicate that higher injection rates and effluent dye concentrations are needed. Sufficient dye will be available during the study to increase dye injection if necessary.

Amount of Dye Required

The amount of dye required and the injection rate will depend on the effluent flow rate. Permit limits for the canneries provide for a combined maximum effluent flow rate of 3.62 million gallons per day (mgd). Targeted initial concentrations of 2 ppm will require dye injection rates of 19 ml/min. For a dye injection period of 13 hours this requires about 4 gallons of dye. Additional dye will available to increase injection rates, if necessary, and to provide a supply for the test injection described below.

FIELD DATA COLLECTION

Dye will be released for approximately 13 hours beginning about 1 hour prior to the start of field measurements and end at or shortly before the cessation of field measurements. A test injection for approximately two hours will be conducted the day prior to the dye test. This test injection will test the injection system, provide an opportunity to test the field sampling equipment, and provide a preliminary assessment of plume trapping levels which will be used to pre-set the drogue and current meter depths. Field equipment requirements for the dilution study, including backup units, are listed in Table 1. A locally chartered vessel will be used to deploy sampling equipment.

A three-person scientific staff will be aboard the vessel to deploy equipment, monitor recorders and record data, and direct sampling activities. One person will be ashore to monitor dye injection and handle any problems with the positioning system. The vessel will be equipped with a hand-held radio in order to allow communication with the dye injection station and cannery personnel.

Field data collection will include the following elements:

- Monitoring of effluent flow rate, dye injection rate, and initial concentration (as described above)
- Positioning with a Mini-Ranger III navigation system, or equivalent (a backup method will be available)
- Drogue releases to indicate the current direction and provide a means of tracking the wastefield as it moves away from the diffuser location
- Vertical profile measurements of dye concentration with depth at selected locations within, at the edge of, and outside the zone of mixing
- Horizontal transect measurements of dye concentration across the width of the wastefield, if possible and appropriate
- Vertical profiles of conductivity and temperature at the same locations as dye measurements and background measurements of conductivity and temperature
- Current speed and direction at two depths (at the diffuser and at the plume trapping level)
- Wind, wave, water level, and general meteorological observations

The first five elements give information on the actual measurement of wastewater dilution and wastefield location. The next three elements are done to record the physical variables of the receiving water and those environmental parameters that control the behavior of the effluent plume.

Dye Injection and Flow Data

Dye pumping rate and effluent flow will be monitored and recorded during the course of the study. The dye pumping rate will be varied, if necessary, to maintain as constant a dye concentration as possible in the effluent. Initial effluent dye concentrations will be measured in duplicate samples taken, at half-hour intervals, downstream of the injection point throughout the duration of the injection periods.

Positioning

Vessel navigation will be done using a Motorola Mini-Ranger III electronic positioning system. A suitable backup system will be available. Use of a Mini-Ranger III will allow maximum flexibility in establishing survey transects and will provide positioning range accuracy of approximately ±2 meters. Three transponder locations will be selected and referenced to horizontal control points. Transponders will be positioned to provide adequate coverage for expected wastefield positions. A map of Mini-Ranger coordinates will be generated locating the diffuser, the water quality sampling stations referenced in the NPDES permits, and the edge of the mixing zone. This map will be used in the field to assist in positioning for dye measurements.

One or two sets of temporary range markers will be set on the shoreline to provide rapid visual positioning of the diffuser location. The diffuser location will be determined from design and/or as built drawings. By marking the diffuser with visual lines of position, in addition to using the Mini-Ranger system, stations can be located quickly.

Drogues will be released at the diffuser location as moving position markers to indicate plume movement. In the vicinity of the diffuser the centerline of the plume will be located by determining the depth of maximum dye concentration. A subsurface drogue, with a surface piercing marker float or flag, will be set for the depth of the plume centerline and released. The drogue will be followed to the edge of the mixing zone, and beyond if necessary, as the dye concentrations are measured. Drogue release points and positions will be recorded according to Mini-Ranger coordinates. Drogues will be recovered at the end of each plume tracking episode.

Dye Measurements

Dye concentrations will be measured with an onboard Turner Designs Model 10 fluorometer, or equivalent. This instrument measures the light emitted from the fluorescent dye solution in response to illumination by a light source in the instrument. The fluorometer will be set up with the appropriate light source and filters for detection of Rhodamine WT dye. The fluorometer will be operated in a flow-through fashion with the ambient water at a particular depth and location pumped directly into the fluorometer by a submersible pump.

Receiving waters in and around the zone of mixing will be sampled in two modes:

- Vertical Profiles: water is pumped continuously through the fluorometer hose intake, which is lowered and raised in the water column in order to document the vertical distribution of dye at selected profiling stations

- Horizontally Transects: water is pumped continuously from a hose positioned at a constant depth while the vessel runs along a transect line

Dye concentrations, in terms of fluorescence readings from the instruments, will be recorded simultaneously with horizontal position and depth. General observations, physical measurements, and any problems will be documented. Rhodamine WT dye fluorescence is highly sensitive to changes in solution temperature. Receiving water temperature, therefore, will be continuously monitored to enable fluorometer data to be corrected during data processing.

At a minimum, vertical profiles will be taken in the vicinity of the diffuser and, following the drogue trajectories, at the edge of the mixing zone. Profiles will also be taken inside and outside the mixing zone along drogue trajectories, as time permits. Horizontal transects will be taken, at a minimum at the edge of the mixing zone. Additional transects inside and outside the mixing zone will be taken as time permits. Decisions concerning the locations and number of profiles and transects will be made in the field by senior project staff familiar with the oceanography of the harbor and the operation of the diffuser. This will maximize operational flexibility and the usefulness of the data collected.

Initial dilution samples will be diluted as necessary and dye concentrations measured at the end of the field operations. Grab samples may be collected if necessary during the course of the field operations. Initial dilution samples and grab samples will be measured using the fluorometer setup in the cuvette mode.

Water Column Density Structure Measurement

InterOcean S4 current meters, discussed below, moored near the diffuser will continuously measure temperature and conductivity at two fixed depths. A SeaBird SBE 19 conductivity, temperature, and depth unit (CTD) will be used simultaneously with the fluorometer at the position of the fluorometer intake to measure and record water column properties. CTD profiles will be available for the same times and locations as dye concentration profiles. Background profiles, outside the effluent plume, will also be taken before, during, and after the dye study period.

Current Measurements

Current speed and direction measurements will be taken during the study. Two InterOcean S4 current meters will be deployed on a single mooring at the diffuser location. One of the meters will be set about 6 feet from the bottom to measure currents acting directly on the diffuser plumes during initial dilution. The other meter will be deployed at the trapping depth of the plume centerline located as described above. These meters will remain at the same depth throughout the dye study. The mooring will be rigged in the field, probably during the dye injection test, to set the upper meter for the correct depth.

Current speed and direction in the vicinity of the diffuser will also be determined with drogues, which will be released at the plume trapping depth as described above. More than one drogue may be released at the same time. Each drogue will be numbered so it can be traced during the course of the study. At the time of release, the release position will be determined with the Mini-Ranger system. Subsequent position determinations will be made when sampling at the drogue locations. Sequential locations of the drogues will be used to calculate average speed and direction along the drogue trajectories.

General Observations

Wind speed and direction will be measured during the course of the dye study using an instrument on board the vessel. Any existing wind stations will be used, if available, to supplement the on-board measurements. Water level will be determined from a staff mounted on a pier piling or from other available tide elevation sources. One of the S4 current meters is equipped with a pressure sensor which will also provide data on water level variations over the period of the field data collection. General meteorological observations will be noted in a field log.

QUALITY ASSURANCE AND QUALITY CONTROL

OBJECTIVE

The quality assurance and quality control objective for the dye studies is to collect measurements of wastefield dilution and dispersion that are of verifiable and acceptable quality. The following procedures will be used to meet the objective:

- Provide verifiable dye injection rates and initial concentrations

- Provide verifiable fluorometric equipment calibration with pre- and post-fluorometer calibration

- Maintain accurate vessel positioning for wastefield measurements

- Provide equipment redundancy (backup equipment)

- Examine dye injection site and downstream sample collection site to verify proper mixing before initial dilution samples are taken

- Examine all data collected to verify instruments are recording/registering data of acceptable quality

- Examine all processed data and data processing methods to verify that analysis techniques are providing the required information

OPERATIONS PLAN

A detailed operations plan for conducting the dilution ratio study will be developed as the basic element of quality assurance and control activities. The operations plan will be based on CH2M HILL's substantial experience with field dye studies. The operations plan will provide the framework for conducting a technically supportable dye study. The operations plan and associated field protocols will be provided in an appendix to the reports. The operations plan will include a preliminary dye injection and field equipment shakedown exercise the day prior to the dye study.

EQUIPMENT CALIBRATION

All equipment will be obtained prior to the beginning of the dye study. Each instrument will be checked on arrival to confirm that it is in working condition. Each instrument requiring calibration will be calibrated immediately prior to the beginning of the dye study and, when appropriate, following the study. Calibration methods for each instrument are described below. Acceptable factory calibrations will be verified for instruments calibrated by the manufacturer.

Dye Pump

The dye pump will be calibrated at the location where it will be used during the dye study. The flow rate will be calibrated with the dye at ambient temperature by discharging dye into a graduated cylinder for a fixed period of time at various flow rate settings. According to the manufacturer, reproducible metering accuracy of greater than 1 percent can be expected when handling medium-viscosity fluids if fluid differential pressure, fluid viscosity, and electric line voltage remain constant. To verify that none of these factors is affecting expected dye flow rates during dye injection, dye flow rates will be verified and logged prior to and at the conclusion of dye injection and cumulative dye volume pumped will be logged at 1-hour intervals during injection.

Fluorometers

Fluorometers will be calibrated according to the manufacturer's specification such that they measure total dye concentration in a range of 0.1 to 100.0 ppb. Standards will be prepared with the dye used in the study, effluent from the canneries, and seawater. Seawater will be collected from the study site prior to the dye study, and fluorometers will be calibrated before going into the field. Immediately following the dye study, new calibration curves will be developed using the same standards as in the pre-study calibration. This second set of calibration curves will be compared to the initial calibration data, after correction for temperature. Both calibration curves will be used to correct or adjust the observed dye concentration and dilution.

CTD and S4 Current Meters

The CTD unit and the current meters will be calibrated to the manufacturer's specifications before conducting the dye study. Calibration results will be used during data reduction and calculation of the water column density structure and current fields as required. Calibration histories will be reported for the units used.

Mini-Ranger

The Mini-Ranger will be calibrated to the manufacturer's specifications prior to conducting the dye study. The unit and transponders will be checked against known distances similar to those to be encountered during the study. A calibration range maintained by the National Ocean Service is used for this purpose.

DATA PROCESSING AND PRESENTATION

Field data will be processed and analyzed to determine the measured dilution of the wastefield at various locations inside, at the edge, and outside of the mixing zone. Water column density profile, water levels and current speed data will also be presented. The data will be presented in graphical and tabular formats.

Field data and procedures will be recorded in field logs on the vessel and at the dye injection station. S4 current meter data are recorded internally in the instruments. These data will be downloaded to a portable computer at the end of the day. The CTD data will be monitored and recorded on computer in real time, critical data will be recorded in the field logs. Fluorometric readings will be recorded in the field logs.

Dilutions will be calculated from fluorometric readings after correction for calibration and temperature. Fluorometer data are processed in four steps as follows:

- **Step 1:** Correct fluorometer outputs for temperature
- **Step 2:** Compare pre- and post-calibrations to determine any drift and to make corrections to the conversion between fluorescence and dye concentration
- **Step 3:** Calculate initial and plume concentrations using information from Steps 1 and 2
- **Step 4:** Calculate dilutions using concentrations (initial and plume) from Step 3

Observed dilutions will be presented as vertical profiles and horizontal transects. Profile and transect locations will be indicated on a base map including the diffuser location and the zone of mixing boundary. Other data will be reported and summarized as appropriate including:

- Tabulations and plots of vertical profile measurements of dye, temperature, and salinity
- Tabulations of wind speed and wind direction
- Plots or tables of water levels and current speed and direction

An interim report will be produced within 30 days of the first dye study. This report will provide recommendations for study plan modifications, if required, for the second dye study. A final report, including results of both dye studies will be produced within 30 days of the second study. Both reports will include an evaluation of the results with respect to compliance with the American Samoa water quality standards. All raw and processed data will be provided in appendices to the dilution study reports.

Table 1
Field Equipment for Dilution Study
(Equivalent or better models may be substituted for some equipment)

Equipment Item	Purpose	Number of Units	Accuracy Standard
Turner Model 10 Fluorometer	Fluorescent dye measurement	2	Detection to 0.1 ppb
Seabird SBE 19 CTD	Measure conductivity, temperature, and depth	1	Conductivity ±0.001 S/m Temperature ±0.001 °C Depth = 0.5% of full scale
Compaq SLT Computer	Set up and record Seabird CTD data	2	4-hour battery (3 packs)
Motorola Mini-Ranger III System	Microwave positioning System 3 transponders	1	±2 meters
MasterFlex Peristaltic Pump	Used for dye injection into effluent at constant rate	2	0.2 ml/min
1/3-hp Submersible Pump	Pumps receiving water from depth through fluorometer	2	230-volt a/c
Motorola Hand-held VHF Radios	Communication ship-to-shore	4	Battery-powered (2-mile range)

ATTACHMENT 2

Comments on the Draft Dye Study Plan

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, Ca. 94105-3901

December 1, 1992

RECEIVED
DEC - 4 1992

Steven L. Costa
Project Manager
CH2M Hill
1111 Broadway
P.O. Box 12681
Oakland, CA 94604-2681

Re: Review of the Joint Cannery Outfall Dye Study Plan

Dear Steve:

We reviewed the canneries' outfall dye study plan and also had Walter Frick of EPA's Office of Research and Development review the the plan. The plan is basically acceptable. However, Dr. Frick had several recommendations and concerns, which are detailed in the attached memo. One of his concerns was that the proposed plume measurement program might overestimate the dilution achieved and recommended a method to counteract this problem. He also had concerns regarding the modeling used for the mixing zone determination not factoring in background concentrations to establish effective dilution based on the discharge's interaction with the ambient water.

We would appreciate your addressing the concerns raised by Dr. Frick in the dye study plan and subsequent analyses.

Sincerely,

Pat Young

Pat Young
American Samoa Program Manager
Office of Pacific Island and Native
American Programs (E-4)

Enclosure

cc: Norman Wei, Star-Kist Seafood Company
James Cox, Van Camp Seafood Company
Pati Faiai, American Samoa EPA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT

ENVIRONMENTAL RESEARCH LABORATORY - NARRAGANSETT
HATFIELD MARINE SCIENCE CENTER
NEWPORT, OREGON 97365

November 25, 1992

PACIFIC ECOSYSTEMS BRANCH
TELEPHONE: (503) 867-4040
867-4040
4029

MEMORANDUM

SUBJECT: Review of Draft Dye Study Plan for Tuna Cannery NPDES Permits

FROM: Walter E. Frick *Walter E. Frick*
Physical & Chemical Processes Team

TO: Janet Hashimoto
Region IX

I have participated in two separate dye studies and know that Steve Costa is himself familiar with dye studies. Based on this experience and my readings of the draft dye study, I find the plan basically acceptable.

However, all parties should be aware of the limitations and pitfalls of dye study work. I think the study team should be able to locate and sample the plume in the nearfield, as described on page 7, though even this task can be difficult and time consuming. The method of then using drogues to follow the water parcel to make subsequent measurements is a fairly standard technique. Short of intensive and extensive monitoring throughout a large area, I do not know of a better way to track the plume.

Given, however, that the nearfield monitoring accurately depicts plume concentrations, most likely this measurement program will tend to overestimate the subsequent dilution achieved. I can think of three reasons to support this conclusion: 1) The depth of the water varies significantly in the vicinity of the diffuser. Because the water column in which the initial dye measurement is made will stretch as it moves into deeper water, the depth of the plume maximum will maintain its relative position, therefore sinking to a greater depth. Thus measurements at drogue depth will no longer represent the plume maximum. 2) The same effect may be accompanied by vertical current shear so that the location of the plume maximum will also be uncertain. 3) Internal wave motion might change the depth and location of the plume. Finally, if the drogue moves into shallower water there is always the danger of getting caught on the bottom.

Of course, attempts can be made to counteract this problem by taking excursions from the drogue location in the effort to find the local maximum. Since knowledge of what direction is perpendicular to the plume centerline will be uncertain, this technique will also suffer uncertainties. However, the existence and importance of the mixing zone makes other locations less relevant. My recommendation is that as much profiling be done along this boundary as possible, using the drogue crossover point as a guide for concentrating the measurement effort.

In addition to the dye study, I examined the Technical Memorandum "Site-specific Zone of Mixing Determination for the Joint Cannery Outfall Project, Pago Pago Harbor, American Samoa." Assuming the density profiles are representative of the conditions of concern, my own limited modeling resulted in initial similar dilution predictions. I have no knowledge about density gradients in tropical waters but do not find what is called a "stronger gradient" on page 12 very strong compared to gradients elsewhere in coastal and estuarine water. The conductivity and temperature measurement program proposed for the dye study should be used to help ameliorate this concern.

The modeling presented in the mixing zone determination study only establishes overall dilutions. It does not factor in the background concentration to establish effective dilution or concentrations based on the interaction of the discharge with existing polluted ambient water. The new EPA guidance on plume modeling "Dilution models for effluent discharges" (Baumgartner, Frick, Roberts, and Fox, 1992) makes such estimates possible. The water quality measurements for Pago Pago Harbor in recent years indicate that water quality standards are exceeded and are occasionally high enough so that, even when they are not exceeded, the presence of a source may cause exceedances near the mixing zone.

The dye program should also help establish whether flow patterns in Pago Pago Harbor are as anticipated in the dye study plan: inflow at the surface and outflow at depth. This is different from the pattern in many estuaries in which outflow generally occurs near the surface.

I hope that the contractor will address these concerns further in forthcoming analyses of the dye studies.

cc: David Young

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JAN 12 1993

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Re: Approval of the Joint Cannery Outfall Dye Study Plan

Dear Dr. Costa:

We have reviewed your letter of December 29, 1992, which provides responses to our comments on the Draft Cannery Outfall Dye Study Plan. We find that the concerns raised by Dr. Walter Frick have been adequately addressed and that the only revision to the draft plan originally submitted is contained in the response to Paragraph 4 regarding the field procedures of vertical profiling. Thus the dye study plan, as submitted with the response to comments, is hereby approved.

Should you have any questions regarding approval of this plan, please contact Pat Young, Office of Pacific Island and Native American Programs, at (415) 744-1591.

Sincerely,

Terry Oda
Chief, Permits Issuance Section
Water Management Division

cc: Norman Wei, Star-Kist Seafood Company
James Cox, Van Camp Seafood Company
Director, American Samoa EPA